The treatment of potential spine injuries by emergency personnel in the prehospital setting

by

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ABSTRACT

Introduction The standard of care for the treatment of potential spine injuries by emergency personnel in the prehospital setting has evolved in recent years. Current practice, however, varies widely, and evidence supporting individual approaches is limited. It remains unclear how new treatment protocols have been applied and how the attitudes of frontline providers influence their care. Additional questions about identifying and preventing additional traumatic spinal cord injury require detailed data that have been rarely reported, partly due to prehospital data-quality challenges. This manuscript-style dissertation aims to describe and analyze patterns of care, attitudes of paramedics to spinal precautions, and the landscape of data quality assessment practices in paramedic research.

Methods Patterns of treatment over the period of protocol changes were investigated in a retrospective database review of electronic patient care reports from the Winnipeg Fire Paramedic Service (WFPS). Attitudes of frontline providers were assessed in a cross-sectional survey of paramedics in the WFPS. To describe the landscape of data quality assessment practices in paramedic research, a scoping review protocol was developed and then applied according to established standards.

Results The rate of treatment with spinal precautions has decreased significantly since 2009, with accompanying changes to several specific elements of care, such as patient positioning and choice of devices. Survey findings indicate that respondents feel that spinal precautions are seen as less important than in the past, that they are treating fewer patients than previously, and that they follow protocol in most situations. A review of data quality assessment practices analyzed 97 articles that met inclusion criteria. Included studies varied widely in many characteristics, but summary findings identify challenges and potential areas for progress in supporting data quality in paramedic research.

Conclusions This thesis illustrates changing patterns of care during the period of protocol revision, accompanied by complex and nuanced attitudes on the part of paramedics towards their practice. These findings update our understanding of how paramedics treat potential spine injuries in the prehospital setting. Additional findings establish the landscape of data quality assessment practices in paramedic research as a necessary precursor to continuing work to link prehospital and in-hospital records.

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INTRODUCTION

Traumatic spinal cord injuries (TSCI) are potentially life-altering events. Characterized by some combination of complete or incomplete motor, sensory, or autonomic deficits and attendant complications, these injuries entail substantial burdens for patients, families, and society. The lifetime economic cost of TSCIs in Canada has been estimated to range from $1.5 to $3.0 million per individual, depending on the injury type.[1] These estimates account for direct and indirect costs, including hospitalization, rehabilitation, prescription drugs, and longer-term morbidity and premature mortality.[1] Those living with TSCI have also described substantial needs imposed by their injuries, ranging from financial help, attendant care, and specialized equipment, to broader infrastructure that promotes accessibility and active living.[2,3]

The annual incidence of TSCI in Manitoba has been reported to be 25.6 per million.[4] The national incidence has been estimated at 53 per million, with an accompanying prevalence of both TSCI and non-traumatic spinal cord injuries (NTSCI) of 2,525 per million.[5] Comparisons across provinces and countries are confounded by inconsistent methodologies and underlying differences in demographics, geography, and culture. However, the annual incidence of TSCI in the United States is reported to be 40.1 per million (with a state high of 83 per million in Alaska), and prevalence is calculated to be 906 per million.[5] Overseas estimates include annual incidences of 14.5 per million in Australia and a prevalence of 250 per million in France.[5]

Given the potentially devastating consequences of these injuries, first-aid and emergency guidelines prioritize preventing or limiting spinal cord damage after trauma. For many years, the standard was consistent across jurisdictions that subscribed to international trauma guidelines: any patient that had sustained trauma with the potential to cause any traumatic spine injury (TSI), even those without cord involvement, was to be immobilized in the supine position using a rigid, body-length board (such as a long backboard), a cervical collar, and head blocks.[6,7] This was termed spinal immobilization (SI). In the early 2000s, some emergency medical services (EMS) agencies began to adopt hospital-based decision tools that allowed practitioners to rule out spine injuries in the field.[8] More recently, growing recognition of the potential harms of immobilization, coupled with scepticism towards its presumed benefit, led to a transition from SI to spinal motion restriction (SMR).[9,10] SMR acknowledges the practical difficulties and potential adverse effects of immobilization, and allows practitioners to vary treatment according to patient presentation. Although specific protocols vary, SMR frequently uses a cervical collar in combination with an ambulance stretcher, rather than a long backboard.[11-13]

Whether SI or SMR, prehospital spinal precautions reflect a consensus that it is desirable to avoid what has been termed “unwanted” or “excessive” motion in the trauma patient.[13, p. 1] Beyond this general agreement, however, the current evidence behind treatment guidelines shows a number of knowledge gaps. Among areas of uncertainty, the transition from SI to SMR has not been widely studied, and it remains unknown if the change in practice has had its intended result or how well frontline practitioners comply with updated guidelines. Along the same lines, the attitudes of providers towards new standards and evolving protocols have been rarely examined. Most fundamentally, it remains unclear which spinal injuries are most at risk of deterioration, how to identify them in the field, and what type of motion causes further harm. Answers to these questions depend on comprehensive data describing the clinical course of patients from their time of injury until hospital discharge, data that has been only infrequently collected.[14-16]

As prehospital trauma care and SMR guidelines continue to evolve, the next generation of protocols will require evidence in each of these areas to improve patient care. This thesis addresses current gaps in research to inform emerging recommendations in the prehospital care of trauma patients. Specifically, it aims to assess the practice of prehospital spinal care in terms of how treatments are being applied and how paramedics view and understand their practice. It also aims to explore data quality in paramedic datasets as a precursor to understanding how prehospital data can be enlisted to answer fundamental questions of patient care. By combining these perspectives, this assessment will be able to provide evidence-based recommendations that reflect the practical realities of prehospital care and inform the next generation of treatment guidelines.

Traumatic spine injuries in the prehospital setting: background

Treatment by mechanism of injury

Traumatic spine injuries necessarily begin with trauma. Not all traumatic events, however, have the potential to injure the spine. Research has shown associations between TSIs and high-risk mechanisms of injury (MOIs): events such as falls from height, high-speed motor-vehicle accidents, axial loads (such as diving accidents), and pedestrians hit by vehicles.[17,18] Some patient groups are also more susceptible to TSI, especially geriatrics and those with underlying conditions such as osteoporosis or ankylosing spondylitis.[19,20] Despite these associations, it remains difficult to predict which trauma patients will have a TSI, whether using MOI or other criteria. Rates of diagnosed injury reported in research range between 0.2% and 3.5% of patients deemed at risk.[17,18] A recent Canadian prehospital study observed a rate of 0.3% for clinically important c-spine injuries in low-risk patients assessed by paramedics.[21] It follows that many more patients are considered at risk of TSI than actually suffer one. Among patients with a spine injury, the number at risk of neurologic deterioration from additional trauma* – patients, that is, who might get worse if not immobilized – is unknown.[22] Early estimates have been shown to have been grossly inflated, and the true incidence is a small subset of an already rare event.[22,23] Overtreatment of anyone at risk of any injury was traditionally accepted as necessary to avoid critical harm.

Figure 0.1 illustrates the clinical pathway of early applications of spinal precautions. The decision to use SI depended on the provider's interpretation: if the MOI had the potential to cause an injury, SI was indicated.[24]

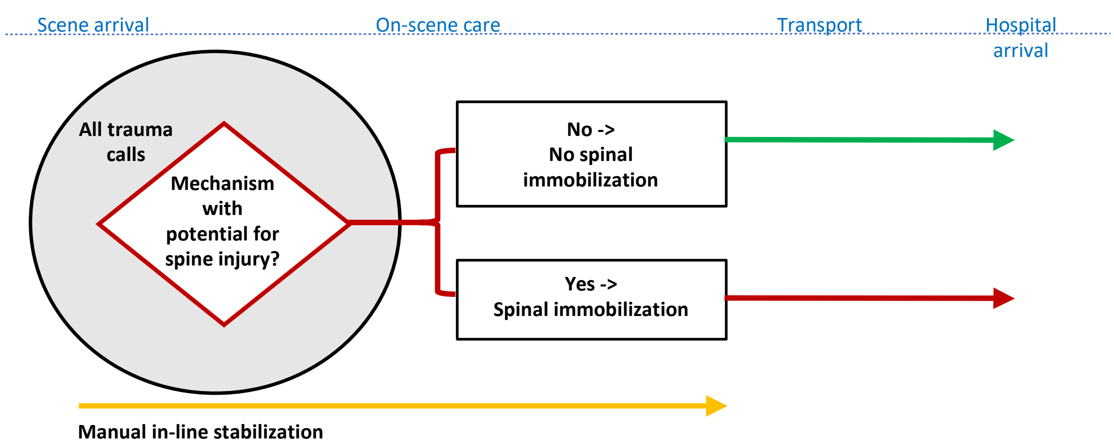

Figure 0.1: Spinal immobilization care pathway, with reference to the clinical decision point based on mechanism of injury.

In this and following figures, the process of manual in-line stabilization, or restricting motion during and through the process of assess and treatment, is represented as an orange parallel line.

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* Neurologic deterioration after trauma has traditionally been called "secondary spine injury". This term is ambiguous, conflating deterioration from both the clinical course of the original insult and additional trauma. This ambiguity has contributed to over-estimates of incidence, and this thesis will use "additional traumatic injury" to refer to new or worsened neurologic deficits after an earlier traumatic injury to the spinal column or cord.

Reconsideration of spinal immobilization

Widespread use of SI led to growing recognition of adverse effects. These range from minor to critical, and include discomfort and anxiety,[25-27] pressure sores,[28-31] respiratory compromise,[32-34] and increased intracranial pressure in head-injured patients.[35-37] Additional complications have also been observed or hypothesized. SI has the potential to cause paradoxically more motion through cervical distraction,[38,39] and to delay treatment or recognition of other, more critical injuries (particularly to airway structures hidden by the cervical collar).[40] Increasing awareness of the potential harms of SI, coupled with growing scepticism towards its presumed benefit, led to a growing consensus that widespread SI protocols could be improved in both assessment and treatment.

Selective immobilization

In the 1990s, researchers and clinicians began to apply clinical criteria instead of using the MOI alone to determine when SI was required in order to standardize assessment and reduce over-treatment.[41] Similar criteria were developed for the same reasons for in-hospital use.[42,43] Among in-hospital clinical decision rules (CDRs), the National Emergency X-Radiography Utilization Study (NEXUS) criteria and the Canadian C-spine Rule (CCR) have been widely studied and adopted.[44,45] In the prehospital setting, many CDRs have been based on hospital versions, while other have been derived and validated uniquely for the prehospital environment.[46,47] While the specific criteria vary, their use has been endorsed by international trauma guidelines.[7,13]

Figure 0.2 displays the integration of a CDR into the prehospital assessment and treatment of a trauma patient.

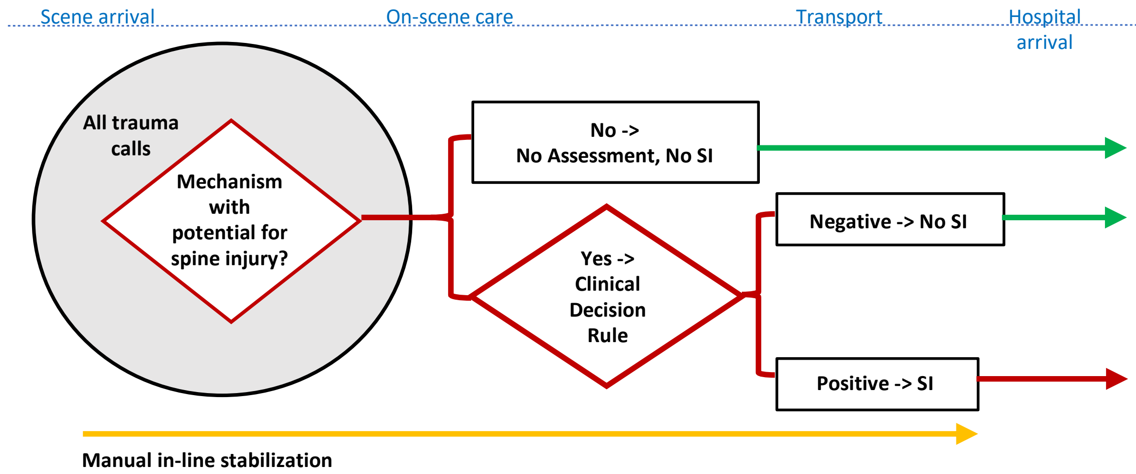

Figure 0.2: Spinal immobilization care pathway, with clinical decision rule.
SI, spinal immobilization

While CDRs in the prehospital setting function to reduce over-treatment (reported specificities vary due to different methods for determining eligible cases of trauma[14]), their application depends on the recognition of an MOI with the potential to cause a spine injury. Many traumatic MOIs are clearly either trivial or dangerous, but those at neither extreme are more difficult to categorize. The risk of a TSI from a fall from standing height, for example, would be considered low, but not zero, depending on the patient and circumstance.[48] Research has demonstrated that categorization of MOIs by emergency personnel is not reliable.[46] One study examining the prehospital application of a selective immobilization protocol audited all trauma calls during the study period (including those cases where patients were not assessed). The authors found that approximately 15% of these patients suffered trauma with the potential to cause a spine injury and, in their judgment, should have had the protocol applied.[46] In another 13% of cases, the MOI was deemed borderline, and patients might have been included or excluded.

If a patient with a minor or borderline MOI is not assessed, it is possible that an injury will go unrecognized and untreated, regardless of the sensitivity of the protocol in use. While it is difficult to quantify how often this might happen, a systematic review of prehospital selective immobilization protocols documented the MOI of all patients with injuries who were not treated.[14] This review observed that elderly patients with minor or low-risk mechanisms appear to make up a disproportionate number of the non-immobilized group. These MOIs might be under-recognized by paramedics applying selective immobilization protocols in this population. (Additionally, this review summarized cases in which the treatment performed did not correspond to the assessment result – cases, that is, where an assessment indicated immobilization and a patient was not immobilized, or where immobilization was not indicated, and a patient received the treatment.[14] These cases are common. Despite non-correspondence rates of over 18% in two studies and one of over 9%, there have been few investigations of the reasons why paramedics might not treat patients as indicated.)

Spinal immobilization to spinal motion restriction

While the application of selective immobilization protocols reduced the number of patients treated, concerns remained that benefit of SI did not outweigh its adverse effects.[49] Gradual revisions to the treatment standard aimed to limit motion in patients at risk of spine injury with more flexible treatment options tailored to patient presentation. Now called SMR, this approach has supplanted SI as the standard of care.[9,10,13] In some contexts, SMR refers to the specific treatment option, usually used in contradistinction to SI. In others, SMR refers to the current practice of treating a patient with spinal precautions, implicitly acknowledging that different treatment options exist. In this thesis, unless otherwise stated, SI will denote the specific practice of treatment with a long backboard, head blocks, and a cervical collar; SMR will refer to current practice that allows different treatment options and will name the specific treatment when needed (such as collar-only or board-and-collar); and spinal precautions will mean the general practice of treating a patient with a suspected spine injury.

Local protocols vary, but SMR in North America typically uses a cervical collar and allows providers to secure a patient to an ambulance stretcher.[13] If practitioners believe more robust packaging is required, SMR protocols discourage the use of the long backboard (except for extrication), and recommend alternatives such as a vacuum mattress. While traditional SI always placed the patient supine, SMR protocols sometimes allow choices among supine, semi-Fowler's, lateral, and a position of patient comfort.[11,50] In the cases of gun-shot wounds and stabbings, guidelines have acknowledged the low chance of benefit from any spinal precautions, coupled with the high chance of other critical, time-sensitive injuries. As a result, SMR is generally contraindicated in cases of penetrating trauma.[51] Figure 0.3 illustrates the introduction of SMR into the clinical pathway.

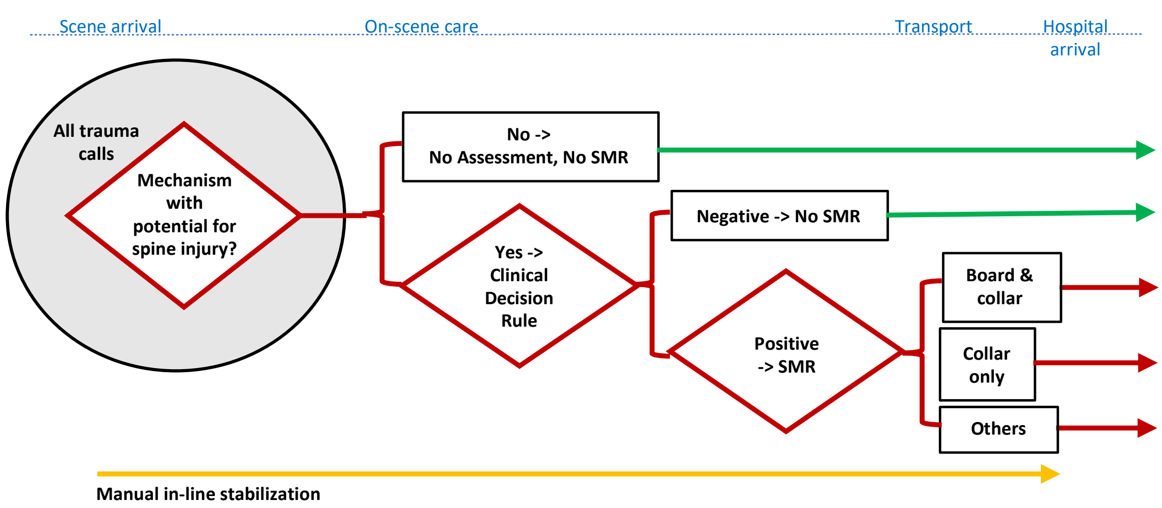

Figure 0.3: Spinal motion restriction care pathway, with clinical decision rule.
SMR, spinal motion restriction

Practice changes since the implementation of SMR principles have not been widely studied, but there are some indications that treatment varies more than might be expected. Early studies confirmed reductions the use of equipment like the long backboard.[11] Others that investigated outcomes noted increases in the number of patients with indications for treatment that did not receive any, as well as an increase in the number of patients with confirmed injuries who received no prehospital SMR.[15,50] Previous work (from this study team and others) on patient movement in realistic and actual prehospital settings documented a range of influences on motion apart from the type of SMR applied, pointing to condition-specific requirements that have not been widely explored.[52-54] Finally, a limited number of studies on provider attitudes found both that traditional SI was seen as over-used (particularly by advanced providers), and that EMS personnel in a variety of jurisdictions support transitions to SMR.[55-58] The relationships between provider attitudes and changing practice, as well as the implications of variable application of protocol-based treatment, have been rarely investigated.

The role of data quality

Determining which spinal injuries are most at risk of deterioration and what type of motion causes further harm depends on data that has not been widely available. Early studies purporting to calculate rates of additional traumatic injury are severely limited in their methodology, amounting to case studies and series with many confounders.[59-62] Recent studies that have tracked the outcomes of spine-injured patients from the prehospital setting have demonstrated no definitive cases of harm associated with the absence of prehospital treatment.[14-

[16,21,63] However, spinal injuries are rare, and it remains difficult to provide conclusive answers based on the accumulated evidence.

The data required for these answers would include specific fields in the paramedic record reported with sufficient detail to capture serial assessments of patients' neurological status in relation to all treatments, interventions, and events and their timing during prehospital care. It would also link this data to similar data in the emergency department as well as in-hospital treatments and final discharge information. Figure 0.4 represents current data sources related to the prehospital treatment of potential spine injuries and their place in the clinical pathway.

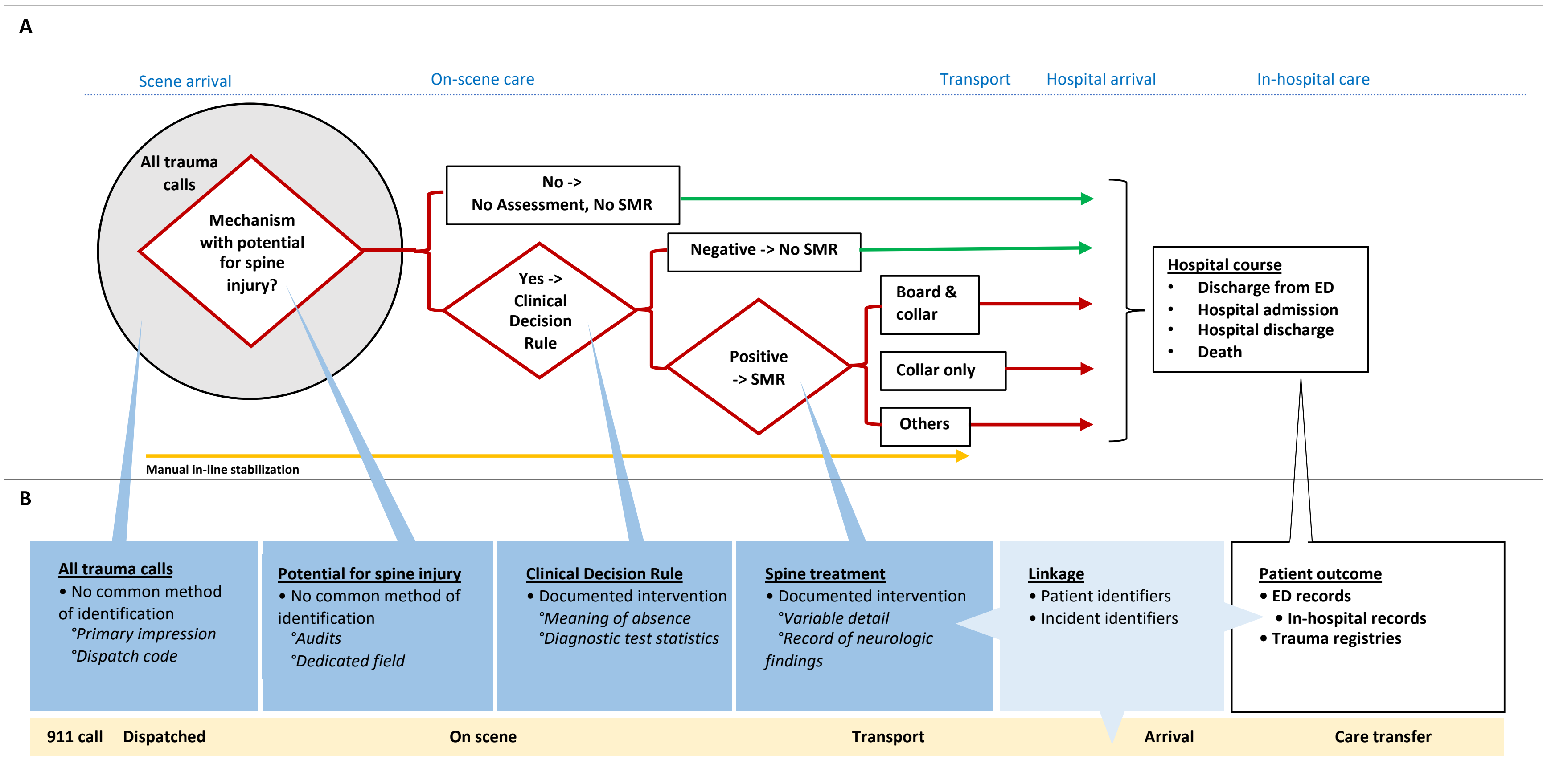

Figure 0.4: Spinal motion restriction care pathway, with data elements. Figure shows (A) clinical decision points in the prehospital setting and (B) data fields in paramedic electronic patient care reports (blue), types of in-hospital records (white), date/times from computer-aided dispatch (yellow), and potential linkage (pale blue). Within paramedic data, methods of data identification and questions related to data collection are indicated *in italics.*
SMR, spinal motion restriction; ED, emergency department.

Existing studies in this area differ in key methodological aspects and demonstrate data-quality limitations in current paramedic datasets. These limitations include variety in how trauma calls are identified, leading to challenges in determining a denominator that defines patients at risk of spine injury.[14] Paramedic-identification of trauma with the potential to cause injury has been shown to be unreliable,[64] and audits are labour-intensive. Documentation rates of MOI tend to have high proportions of missing values.[65,66] More generally, identification of trauma calls remains inconsistent across paramedic research.[67,68] Records of paramedic care, frequently in the form of electronic patient care reports (ePCRs), differ in the precision of timestamps, the comprehensiveness of available variables, and what information they require.[65,69] Information in free-text form, while common, poses problems for data-extraction and categorization[65,70]; as result, explanations for why treatment occurs the way it did are largely hidden from view. Finally, linkage to hospital outcomes has been acknowledged as a chronic limitation and barrier to outcome assessment in paramedic research – yet essential to both developing research capacity and improving patient care.[71,72]

GENERAL AIM OF THESIS

The evolution of spinal precautions from SI to SMR can be characterized as an incremental and uneven transition that has been informed by low-quality evidence, consensus, and local opinion. Current guidelines are varied and inconsistent.[13,73,74] If future guidelines are to improve patient care, they will require better data than currently exists. Among multiple knowledge gaps, several have direct relevance for treatment. First, the state of current practice remains poorly described. In a context of recent change to both assessment practices (through the introduction of selective immobilization protocols) and treatment guidelines (in the transition from SI to SMR), the available literature on current practices shows variations in care that would not be expected. Second, the attitudes and beliefs among providers in relation to changing practice have not been investigated. Information from field practitioners can be expected to affect, if not determine, patterns of care. And third, with few exceptions, the link between prehospital treatment and patient outcomes has not been well established or sufficiently reported. This absence of data reflects chronic and significant barriers to linking prehospital datasets to emergency department (ED) or in-hospital records – a limitation that has been frequently cited as an obstacle to progress within the field of paramedic research as a whole.[75] In the context of current practices and the state of knowledge, this thesis aims to describe and analyze the patterns of care, the attitudes of paramedics to spinal precautions, and the landscape of data quality assessment (DQA) practices in paramedic research.

Purpose, objectives, and rationale of manuscripts

Manuscript 1 – Database Analysis

Purpose: To describe and analyze patterns of care in the application of prehospital spinal precautions over the timeframe of the transition from SI to SMR in one urban EMS agency.

Objectives:

- Calculate and analyze the rate of treatment with spinal precautions with reference to known and hypothesized influences on practice.
- Describe and analyze patient and practice characteristics over time.

Rationale: Available research signals variations in care that would not be expected. In a context of evolving practice standards, this manuscript addresses a gap in knowledge about how SMR protocols have been applied.

Manuscript 2 – Paramedic Survey

Purpose: To document paramedics' attitudes, observations, and self-reported practices around the treatment of potential spine injuries in the prehospital setting.

Objectives:

- Analyze response data for latent constructs in paramedics' conception of the topic.
- Investigate responses for associations with participant characteristics.
- Examine provider agreement in areas of practice drawn from prior research.
- Analyze the content of free-text responses for additional understanding of attitudes and behaviours.

Rationale: A limited number of previous studies have documented attitudes of emergency personnel both to SI and new approaches under SMR. This survey relates paramedics' attitudes to current practice, changes over time, and specific practice questions drawn from prior research.

Manuscript 3 – Scoping Review Protocol

Purpose: To register a peer-reviewed protocol for the conduct of a scoping review of data quality assessment (DQA) practices in research in paramedicine.

Objectives:

- Detail the background, rationale, question, and methods for a scoping review.

Manuscript 4 – Scoping Review

Purpose: To describe DQA practices in research in paramedicine.

Objectives:

- To assess the range, extent, and nature of data quality assessment practices in paramedic research.
- To determine whether practices would benefit from a framework unique to paramedic research.

Rationale: Mapping the landscape of DQA practices in research in paramedicine is a necessary precursor to future data-linkage studies – studies that will advance knowledge on the relationship between prehospital treatment and patient outcomes.

RESULTS

Overview

This thesis presents results in the four following manuscripts.

Manuscript 1 – Patterns of change in prehospital spinal motion restriction: a retrospective database review.

- Authors: McDonald, N, Kriellaars, D, & Pryce, RT.
- Status: Published in *Academic Emergency Medicine*, 02 February 2023 https://doi.org/10.1111/acem.14678
- Contribution: I was primarily responsible for framing the study questions, coordinating data extraction, data cleaning and analysis, interpretation, writing, and submission.
- Rights and permissions: Copyright is maintained by the authors. The published article is licensed under a Creative Commons Attribution Non-Commerical 4.0 International License, https://creativecommons.org/licenses/by-nc/4.0/. The article has been re-formatted to manuscript form with minor edits. No other changes have been made.

Manuscript 2 – Paramedic attitudes towards prehospital spinal care: a cross-sectional survey

- Authors: McDonald, N, Kriellaars, D, & Pryce, RT.
- Status: Published in *BMC Emergency Medicine*, 2022 22:162, https://doi.org/10.1186/s12873-022-00717-2
- Contribution: I was primarily responsible for drafting and conducting the survey development project, drafting the final survey instrument, and dissemination. I led

quantitative analysis of the results. Content analysis was conducted in cooperation with Dr. Pryce. I was primarily responsible for interpreting results, drafting the manuscript, submission, revisions, and responses to reviewers.

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Manuscript 3 – Database quality assessment in research in paramedicine: a scoping review protocol

- Authors: McDonald, N, Kriellaars, D, Doupe, MB, Giesbrecht, G, Pryce, Rob T.
- Status: Published in *BMJ Open* 2022;12:e063372. http://dx.doi.org/10.1136/bmjopen-2022-063372
- Contribution: I was primarily responsible for developing the study question, conducting the background literature review, drafting the manuscript, revising, and responding to reviewers.
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Manuscript 4 – Database quality assessment in research in paramedicine: a scoping review

- Authors: McDonald, N, Little, N, Kriellaars, D, Doupe, MB, Giesbrecht, G & Pryce, RT.
- Status: In preparation for submission.
- Contribution: I was primarily responsible for designing and executing the search. All screening tasks were shared among NM, RT, and NL. I led the data extraction, analysis, and synthesis, and prepared this draft.

Patterns of change in prehospital spinal motion restriction: a retrospective database review

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Presentations
Some of the data in this work was presented as an abstract at the National Association of EMS Physicians Scientific Assembly, January 2022, San Diego, CA. Those data have been re-analyzed and constitute original work in the current manuscript.

ABSTRACT

Background Acute management of trauma patients with potential spine injuries has evolved from uniform spinal immobilization (SI) to spinal motion restriction (SMR). Little research exists describing how these changes have been implemented. This study aims to describe and analyze the practice of SMR in one emergency medical services (EMS) agency over the timeframe of SMR adoption.

Methods This was a retrospective database review of electronic patient care reports from 2009 to 2020. The effects of key practice changes (revised documentation and a collar-only treatment option) were analyzed in an interrupted time series using the rate of spinal precautions as the primary outcome. Secondary outcomes included patient age, sex, acuity, mechanism of injury (MOI), treatment provided, cervical-collar size, and positioning. These were assessed for changes from year to year by Poisson regression. Associations between patient and treatment characteristics were investigated with binomial logistic regression.

Results There were 25,747 instances of spinal precautions included. Among all patients, the median age was 40 (interquartile range, 24 – 56), 58% (14,970) were male, and 20% (5062) were high-acuity. The rate of spinal precautions declined from 31.2 to 12.7 treatments per 100 trauma calls each month. The proportion of high acuity patients increased by 9.6% per year on average (95% CI: 8.7%, 10.0%). When first available, collar-only treatment was provided to 47% of patients, rising by 6.3% per year (95% CI: 3.2%, 9.5%), to 60% in 2020. Collar-only treatment (as compared to board-and-collar) was more likely to be applied to low-acuity patients (as compared to high): OR 3.01 (95%C I: 2.64, 3.43).

Conclusions This study shows decreasing spinal precautions treatment and changing patient and practice characteristics. These patterns of care cannot be attributed solely to formal protocol changes. Similar patterns and their possible explanations should be investigated elsewhere.

INTRODUCTION

International training guidelines teach the treatment of potential spine injuries as a core skill in both the emergency department and the prehospital environment.[1,2] During the last decade, however, these guidelines have been substantially revised. Past practice, termed spinal immobilization (SI), most often positioned patients at risk of spine injury supine on a long, rigid backboard, and immobilized them with straps, a rigid cervical collar, and head blocks. More recently, spinal motion restriction (SMR) acknowledges the adverse effects of immobilization as well as the limitations of its potential benefits, and typically allows more leeway in treatment options depending on patient presentation.[3,4] Despite widespread adoption of the principles of SMR, practices and specific guidelines vary. The role of the cervical collar, for example, differs widely among jurisdictions,[5-11] and it remains unclear which devices and procedures are most effective at limiting potentially harmful motion.

Within the existing research on SMR, studies describing practice changes around the implementation of new protocols have confirmed expected decreases in the use of the long backboard and increases in alternatives, such as collar-only treatment and devices such as the vacuum mattress.[12-14] Other studies have compared different treatment techniques and found a range of factors and scenarios that influence patient motion apart from the specific device applied, including driving habits,[15,16] extrication,[17] and patient behavior.[18,19] Additional research has examined patient characteristics and outcomes after introducing new guidelines, observing not only substantial under-treatment among patients who met criteria for precautions, but also increases in the number of patients with confirmed injuries who received no treatment from emergency medical services (EMS).[20,21] While a small number of additional studies using high-level population data have observed no increase in a final diagnosis of spinal cord injury after SMR,[22,23] the prospects of variable practice, ineffective interventions, and patients not receiving the treatment intended for their injury remain a concern.

If standards for the acute management of spine injuries are to progress, treatment must continue towards optimizing patient protection while avoiding further harm.[24] In general, there is scant research describing prehospital patients who receive treatment for potential spine injuries and whether that treatment corresponds to local guidelines[25,26]; there is less that describes these patients and their treatment during the period of practice change. This information, however, is necessary to begin to understand how SMR guidelines have been integrated into frontline care and how future guidelines might be improved. Therefore, the purpose of this study is to describe and analyze the practice of SMR in one urban, North American EMS agency over the timeframe of SMR adoption, with specific attention to the rate of treatment and patient and practice characteristics.

METHODS

Reporting of this study follows The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[27]

Design, setting and background

This is a retrospective review of records of the Winnipeg Fire Paramedic Service (WFPS) from April 2009 through February 2020, a period determined by the availability of electronic patient care reports (ePCRs) and the onset of COVID-19. Ethical approval was obtained from the local research ethics board (HS24193 [H2020:376]).

The WFPS serves an urban population of approximately 750,000 and employs basic life support (BLS) first response and combined BLS and advanced life support (ALS) follow-up care and transport. Its BLS and ALS personnel (termed Primary and Advanced Care Paramedics, respectively) are trained to national standards at each level, with ALS providers trained additionally in Prehospital Trauma Life Support.[2] In common with many similar agencies, local treatment guidelines for potential spine injuries have been revised in several ways. 1) In March 2009, the service implemented a selective immobilization protocol resembling others deployed in the prehospital setting and similar to the NEXUS criteria.[28-30] Under this protocol, any patient who has experienced trauma with the potential to cause a spine injury receives spinal precautions if any of six indications are present: a reduced level of consciousness or altered mental status, signs of head trauma, signs of intoxication, a distracting painful injury, spine tenderness, or a focal neurologic deficit. 2) In an effort to increase rates of documentation, the service implemented a logic rule in the ePCR in July 2012 that obliges attending paramedics to record the indications for spinal precautions in all cases where it was considered or applied, or to confirm that a traumatic mechanism of injury (MOI) was not sufficient to cause a spine injury. 3) Cases of isolated penetrating trauma were exempted from spinal precautions in November 2014.[2,31] 4) In April 2016, treatment guidelines were revised to allow for collar-only treatment in low-risk scenarios (defined as the patient being ambulatory prior to paramedic arrival).[32] Other elements of treatment remained the same, including direction to secure the patient to the stretcher in the supine position.

As accepted terminology remains variable, this study will use SI to denote the practice of immobilizing a patient on a long spine board with a combination of a cervical collar, head blocks, and straps. SMR will refer to treatment after 2016, when providers gained to option to treat either as previously or with only a cervical collar. Since this study straddles the adoption of SMR principles, the intervention will be described as spinal precautions unless specifically discussing one or the other. “Selective immobilization” refers to the clinical decision protocol that determines the need for spinal precautions in the presence of an MOI with the potential to cause a spine injury (the term “immobilization” has been kept since SI was the standard treatment when the protocol was adopted).

Data selection, outcomes, and analysis

Cases were drawn from the database of ePCRs based on the documented presence of spinal precautions as an intervention. Paramedics in this service document care in the ePCR using a laptop computer (Panasonic Toughbook, Panasonic Canada Inc., Mississauga, ON), where all information is entered either manually by keyboard or by touchscreen. A system of logic rules supports data quality by forcing completion of essential fields with valid entries.

The primary outcome is the rate of spinal precautions during the study period. Rates of splinting and wound care were also collected as proxy measures of the incidence of trauma care over time. Secondary outcomes include patient- and practice-related factors associated with potential changes over time. Patient-related factors include age, sex, acuity, MOI, and indications for treatment. Patients were classified as high acuity if they were transported emergently or if they met criteria for diversion to the local trauma center. Trauma-center criteria follow guidelines published by the Center for Disease Control in collaboration with the American College of Surgeons and feature sections based on vital signs, anatomical injury, and MOI.[33] The record of MOI consists of both a pre-set list and a free-text field. Neither is mandatory to complete documentation. Entries were collected in main categories: fall, motor vehicle accident (MVA), assault, sports-related, and other. The "other" category included all items that were not easily grouped, such as injuries related to fire, lightning, drowning, and machinery accidents. Blank fields were marked as "not reported". Factors related to practice include cervical-collar size, patient positioning, the proportion of collar-only use (after protocol change), and the rate of treatment of penetrating trauma. Among these, cervical-collar size has not been previously reported in detail. However, sizing a cervical collar to a patient is described as proper technique to ensure adequate restriction and is specified in clinical guidelines.[2,5] A small body of research has investigated the effects of under- or over-sized collars in simulated settings, and improper sizing has been reported in a large proportion of simulated applications.[34-36] Cervical-collar size has been included here to describe and analyze practice in field conditions.

The primary outcome and comparison interventions were summarized as monthly counts and expressed in terms of 100 trauma calls each month. Any call record with a primary impression related to trauma was included in the denominator.[37] The rate of each intervention was analyzed by segmented regression in an interrupted times series using the 2012 documentation change and the 2016 SMR treatment change as interruptions. The implementation of selective immobilization marks the start of the study period (determined by the availability of ePCR data). The exemption of isolated penetrating trauma was considered outside of the interrupted times series due to the small number of cases at any time.

Data from each treatment was plotted as a time series over the 131 months of the study period. Figure 1.1 illustrates the raw rate of spinal precautions as well as the portion of treatments attributable to a constant monthly seasonal effect over the study duration. Moving-average seasonally adjusted rates were then used to develop models for segmented regression of the ITS. This approach assumes that series values are not autocorrelated, or related to themselves over time.[38,39] If present, autocorrelation can be accounted by for re-specifying the model or including autoregressive or moving-average terms.[38-40] In this case, preliminary testing for spinal precautions showed persistent residual autocorrelation with a linear model (Box-Ljung test, X-squared = 74.7, df = 24, $p < 0.001$). After comparing results among different potential solutions, a quadratic model with no autoregressive or moving-average terms yielded no significant residual autocorrelation: Box-Ljung test, X-squared = 33.0, df = 24, $p = 0.1$. This model also resulted in a marginally improved fit compared to the linear version: adjusted r^2, 0.949 versus 0.938; Akaike's Information Criteria, 507.6 versus 517.0; Bayesian Information Criteria, 530.2 versus 536.8; Likelihood Ratio, 11.42, $p < 0.001$. This model met the assumptions required for segmented regression of an ITS and was used for analysis. Candidate models for the comparison trauma treatments were assessed using a similar process. These showed no improved fit with a quadratic term and linear models were applied.

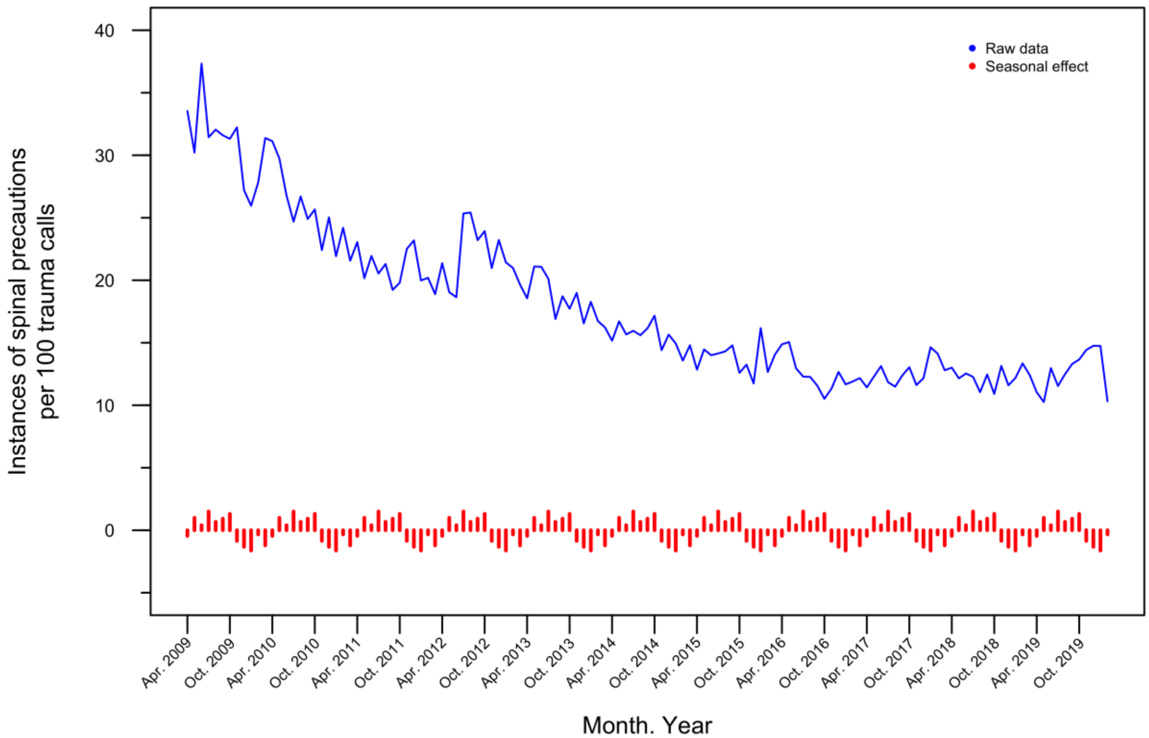

Figure 1.1: Time series of prehospital spinal precautions.
Raw data plotted by month, 2009 – 2020. Seasonal effect averaged for each month over the study period, showing the monthly maximum (1.4, July) and minimum (-1.6, January).

Secondary outcomes are reported in terms of raw counts and percentages (or median and interquartile range in the case of age), both overall and for each year of the study. As recent epidemiological literature has observed increasing rates of traumatic spine and spinal cord injuries among elderly women (in contrast to prior findings of higher incidence among young men),[41-43] proportions of women over 65 and men under 40 among the study population were also calculated. Changes in each factor over time were assessed using Poisson regression fitted to the factor count, with the year modelled as a continuous variable and the count denominator included as an offset.[44]

To investigate associations between treatment practices and patient characteristics, key treatments were dichotomized based on findings: treatment choice (collar-only compared to board-and-collar), patient positioning (supine compared to all others), and cervical-collar size ("no-neck" compared to all others). These categories were related to patient traits by binomial logistic regression and reported as an adjusted odds ratio. Treatment choice was available only after the protocol change and is therefore reported from 2016 – 2020. The same timeframe was chosen for patient positioning, as the vast majority of treatments prior to 2016 were supine. Collar size was assessed for the entire study period as well as 2009 – 2015 and 2016 – 2020; with minimal difference in outcomes, calculations for the entire study period are reported. All analyses were performed in R, version 4.0.5 (Foundation for Statistical Computing; Vienna, Austria). A threshold of alpha < 0.05 was considered statistically significant.

RESULTS

During the study period 25,854 cases of spinal precautions were identified. Of these, 107 (0.4%) were found to be duplicates and removed, leaving 25,747 included records of treatment out of 141,445 trauma calls. Among all included cases, there were 70 (0.3%) missing an entry for sex, none missing an entry for age, and 739 (2.9%) missing valid information on acuity. These cases were excluded from summary statistics. The median age of included patients was 40 (interquartile range, 24 – 56) and 14,970 (58%) were male. Overall, 5,062 patients (20%) were classified as high-acuity. The MOI was not reported in 9,528 cases (37%).

Figure 1.2 shows the seasonally adjusted rate of spinal precautions per 100 trauma calls each month in an interrupted times series segmented by: a) the documentation change that mandated recording the spine assessment in any case of trauma with the potential to cause a spine injury; and b) the protocol change to SMR, which allowed for collar-only treatment.

Interventions for wound care and splinting are also displayed. Table 1.1 shows the coefficients for the level changes at each interruption and trend change during each period.

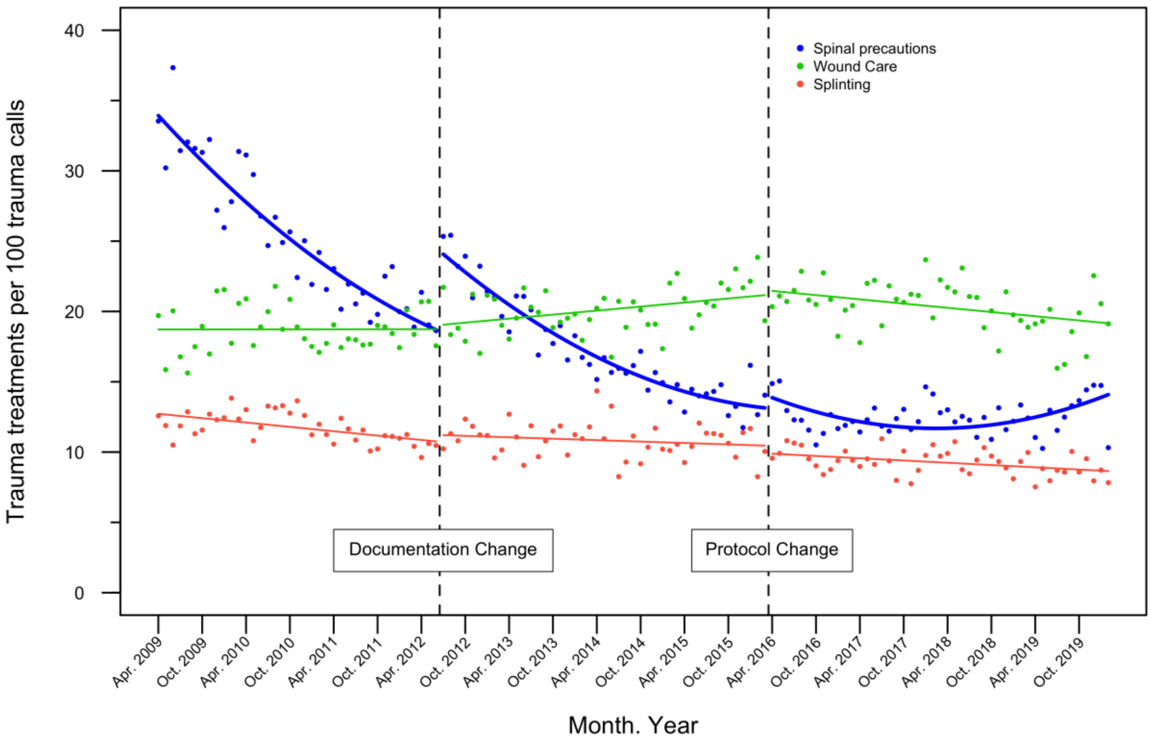

Figure 1.2: Interrupted time series of prehospital trauma treatments, 2009 – 2020. Seasonally adjusted data plotted by month (shown as dots), with accompanying lines of best fit for wound care and splinting (linear) and spinal precautions (quadratic).

Table 1.1: Trend and level change coefficients for the interrupted time series of prehospital trauma treatments

All values expressed in terms of treatments per 100 trauma calls (95% CI)

	Spinal precautions	Wound Care	Splinting
Intercept	34.5 (33.5, 35.5)***	18.7 (17.6, 19.8)***	12.8 (12.1, 13.4)***
Before Period–Trend change[1]	-0.57 (-0.65, -0.50)***	0.0004 (-0.05, 0.05)	-0.05 (-0.08, -0.02)***
Documentation–Level change	5.8 (4.6, 7.1)***	0.27 (-1.2, 1.7)	0.46 (-0.39, 1.3)
Middle Period –Trend change[1]	-0.21 (-0.36, -0.06)**	0.05 (-0.01, 0.10)	0.03 (-0.001, 0.07)
Protocol–Level change	0.92 (-0.24, 2.1)	0.35 (-1.0, 1.8)	-0.55 (-1.4, 0.27)
After Period–Trend change[1]	-0.15 (-0.30, 0.01)	-0.10 (-0.15, -0.04)***	-0.01 (-0.04, 0.02)
Trend^2	0.004 (0.003, 0.006)***	-	-

The "Trend^2" coefficient reflects the additional term in the quadratic model.
Estimates can be derived by adding it to the trend coefficient in each period according to the formula:
"Trend^2" x k^2, where k is the number of months in the period corresponding to the estimate

1. Trend changes denote change from the preceding value.

*P values: * < 0.05; ** < 0.01, *** < 0.001*

The rate of treatment with spinal precautions declined significantly during the first two time periods. The documentation change was associated with a significant level increase in the rate of spinal precautions of 5.8 treatments per 100 trauma calls (95% CI: 4.6, 7.1). The protocol change allowing collar-only treatment was not associated with a significant change in rate, and the final time period showed no significant trend change. In comparison, neither wound care nor splinting showed any substantial level or trend changes. Evaluating the change in the rate of each intervention between the first and last 12 months of the study period, spinal precautions declined from 31.2 to 12.7 treatments per 100 trauma calls – a 59% (95% CI: 56%, 62%) decrease – while instances of wound care increased from 18.6 to 19.0 treatments per 100 trauma calls (2.2% [95% CI: -3.0%, 7.1%]) and splinting decreased from 12.1 to 8.6 (-28% [95% CI: -22%, -35%]).

Table 1.2 describes patient characteristics over the study period. The age (median 40, interquartile range 24 – 56) and sex (58% male) of patients treated with spinal precautions did not significantly change over time, but the proportion of female patients over age 65 significantly decreased by -2.8% per year (95% CI: -4.0%, -1.5%). Decreasing overall treatment was accompanied by a significantly increasing proportion of high acuity patients. These made up 11% of all treatments in 2009, but 31% in 2020, an average annual percent change of 9.6% (95% CI: 8.7%, 10.0%).

Table 1.2: Age, sex, and acuity of all patients treated with spinal precautions, 2009 – 2020
All cells reported as n (%) except: Cases; Age, Median (IQR); Mean annual percent change (95% CI)

	Cases	Age, Median (IQR)	Pediatric (<16)	Geriatric (>65)	Male	Male, <40	Female, >65	High acuity
Total	25747	39.7 (24.3-56.1)	2030 (7.9)	4142 (16)	14970 (58)	7808 (30)	2300 (8.9)	5062 (20)
2009 (04-12)	3417	40.5 (23.5-57.6)	301 (8.8)	646 (19)	1972 (58)	1005 (29)	361 (11)	390 (11)
2010	3652	40.0 (24.3-57.0)	288 (7.9)	634 (17)	2087 (57)	1076 (30)	373 (10)	529 (15)
2011	3007	39.9 (23.2-55.9)	269 (8.9)	466 (16)	1730 (58)	904 (30)	275 (9.1)	488 (16)
2012	2985	37.9 (23.3-55.4)	239 (8.0)	477 (16)	1708 (57)	957 (32)	271 (9.1)	537 (18)
2013	2337	40.0 (23.9-55.2)	202 (8.6)	341 (15)	1302 (56)	668 (29)	199 (8.5)	441 (19)
2014	1938	40.6 (24.8-55.9)	151 (7.8)	292 (15)	1132 (58)	573 (30)	147 (7.6)	415 (21)
2015	1686	39.8 (25.1-55.1)	136 (8.1)	257 (15)	1036 (61)	541 (32)	132 (7.8)	377 (22)
2016	1622	37.7 (24.2-55.0)	127 (7.8)	217 (13)	991 (61)	541 (33)	115 (7.1)	392 (24)
2017	1632	37.9 (24.9-54.9)	125 (7.7)	236 (15)	1001 (64)	534 (33)	117 (7.2)	392 (24)
2018	1603	40.0 (26.0-57.6)	97 (6.1)	245 (15)	916 (57)	470 (29)	136 (8.5)	498 (31)
2019	1651	40.7 (26.4-57.8)	83 (5.0)	286 (17)	972 (59)	482 (22)	152 (9.2)	536 (33)
2020 (01-02)	217	44.3 (29.3-59.3)	12 (5.5)	45 (21)	123 (57)	57 (26)	22 (10)	67 (31)
Mean annual percent change (95% CI)		0.1 (-0.1, 0.4)	-3.3*** (-4.6, -1.9)	-1.5** (-2.5,-0.6)	0.5 (-0.1, 1.0)	0.4 (-0.3, 1.0)	-2.8*** (-4.0, -1.5)	9.6*** (8.7, 10)

*P values: * < 0.05, ** < 0.01, *** < 0.001*
IQR, interquartile range.

Among reported MOIs, instances of falls and MVAs were most common (each 23%), followed by assaults (15%), sports (2.0%) and other events (0.7%). During the study period, there were small but significant decreases in the proportions of falls, MVAs, and assaults, with a commensurate increase in instances of non-reporting (4.1% on average per year [95% CI: 3.5, 4.8]). There were no significant changes in the remaining categories. Detailed information on the documentation of MOIs is available in Appendix 1.1, "Mechanisms of injury". Similar information on the documented indications for treatment is available in the Appendix 1.2, "Treatment indications".

Table 1.3 outlines the use and sizing of cervical collars. Throughout the study period, the "no-neck" collar was used more frequently than any other single size (65%). This was the smallest of standard available options for adult patients. (Pediatric patients receive pediatric collars unless adult collars are appropriate; documentation does not differentiate among different pediatric sizes.) "No-necks" accounted for 71% of all patients treated in 2009 (and peaked at 75% in 2010 and 2011), but their use decreased over time by -3.8% per year (95% CI: -4.2%, -3.3%), to 49% in 2020. This decrease was matched with a corresponding decrease in "short" collars and increasing use of "regular" and "tall" sizes. The largest yearly change was in the increase in collars omitted, refused, or improvised, from 2.0% in 2009 to 8.3% in 2020, or 13% per year (95% CI: 11%, 15%).

Table 1.3: Cervical-collar documentation of all patients treated with spinal precautions, 2009 – 2020
All cells reported as n (%) except: Cases; Mean annual percent change (95% CI)

	Cases	No-neck	Short	Regular	Tall	Pediatric	Other[1]	Not recorded
Total	25747	16822 (65)	3151 (12)	3450 (13)	104 (0.4)	939 (3.6)	838 (3.3)	443 (1.7)
2009 (04-12)	3416	2426 (71)	603 (18)	160 (4.7)	13 (0.4)	145 (4.2)	69 (2)	0 (0)
2010	3652	2747 (75)	499 (14)	179 (4.9)	4 (0.1)	139 (3.8)	84 (2.3)	0 (0)
2011	3008	2259 (75)	362 (12)	137 (4.6)	10 (0.3)	117 (3.9)	55 (1.8)	68 (2.3)
2012	2986	2020 (68)	404 (14)	254 (8.5)	10 (0.3)	87 (2.9)	76 (2.5)	135 (4.5)
2013	2337	1519 (65)	279 (12)	287 (12)	10 (0.4)	80 (3.4)	83 (3.6)	79 (3.4)
2014	1938	1187 (61)	210 (11)	356 (18)	9 (0.5)	62 (3.2)	66 (3.4)	48 (2.5)
2015	1686	995 (59)	192 (11)	341 (20)	11 (0.7)	68 (4.0)	49 (2.9)	30 (1.8)
2016	1622	951 (59)	160 (9.9)	368 (23)	13 (0.8)	62 (3.8)	45 (2.8)	23 (1.4)
2017	1632	915 (56)	131 (8.0)	403 (25)	7 (0.4)	61 (3.7)	92 (5.6)	23 (1.4)
2018	1603	872 (54)	152 (9.5)	381 (24)	7 (0.4)	63 (3.9)	113 (7)	15 (0.9)
2019	1650	824 (50)	140 (8.5)	523 (32)	10 (0.6)	48 (2.9)	88 (5.3)	17 (1.0)
2020 (01-02)	217	107 (49)	19 (8.8)	61 (28)	0 (0)	7 (3.2)	18 (8.3)	5 (2.3)
Mean annual percent change (95% CI)		-3.8*** (-4.2, -3.3)	-6.4*** (-7.5, -5.3)	21*** (20, 23)	8.4** (2.2, 15)	-1.4 (-3.4,0.6)	13*** (11, 15)	3.7* (0.7, 6.7)

1. Includes those omitted, refused by patient, or improvised

*P values: * < 0.05, ** < 0.01, *** < 0.001*

As shown in Table 1.4, slightly under half of eligible patients (47%) were treated with only a cervical collar in 2016, the first partial year after the protocol change allowing that treatment. This proportion increased by an average of 6.3% per year (95% CI: 3.2%, 9.5%), rising to 60% in 2020. Patient positioning changed significantly in all categories, with the largest changes appearing after 2016 in most (although protocol still mandated supine positioning for all patients treated with spinal precautions, whether with only a collar or board and collar). Overall, supine positioning decreased on average by -3.1% per year (95% CI: -3.5%, -2.7%) while all others increased. The use of semi-Fowler’s positioning increased 47% on average per year (95% CI: 44%, 50%), rising from 0.8% of all patients treated in 2009 to 25% in 2020.

Table 1.4: Documentation of patient positioning and collar-only treatment of all patients treated with spinal precautions, 2009 – 2020

All cells reported as n (%) except: Cases; Mean annual percent change (95% CI)

	Cases[1]	Supine	Semi-Fowler's	Sitting / Fowler's	Other[2]	Not recorded	Collar only[3]
Total	25747	22712 (88)	1428 (5.5)	475 (1.8)	406 (1.6)	726 (2.8)	3255 (51)
2009 (04-12)	3416	3218 (94)	26 (0.8)	32 (0.9)	37 (1.1)	104 (3.0)	-
2010	3652	3467 (95)	26 (0.7)	28 (0.8)	35 (1.0)	96 (2.6)	-
2011	3008	2864 (95)	22 (0.7)	28 (0.9)	50 (1.7)	43 (1.4)	-
2012	2986	2758 (92)	51 (1.7)	48 (1.6)	55 (1.8)	73 (2.4)	-
2013	2337	2165 (93)	40 (1.7)	34 (1.5)	44 (1.9)	54 (2.3)	-
2014	1938	1799 (93)	43 (2.2)	22 (1.1)	38 (2.0)	36 (1.9)	-
2015	1686	1560 (93)	50 (3.0)	14 (0.8)	31 (1.8)	31 (1.8)	-
2016	1622[3]	1282 (79)	216 (13)	50 (3.1)	34 (2.1)	40 (2.5)	584 (47)
2017	1632	1198 (73)	272 (17)	72 (4.4)	22 (1.3)	68 (4.2)	803 (49)
2018	1603	1153 (72)	275 (17)	73 (4.6)	28 (1.7)	74 (4.6)	813 (51)
2019	1650	1106 (67)	353 (21)	67 (4.1)	28 (1.7)	97 (5.9)	924 (56)
2020 (01-02)	217	142 (65)	54 (25)	7 (3.2)	4 (1.8)	10 (4.6)	131 (60)
Mean annual percent change		-3.1*** (-3.5, -2.7)	47*** (44, 50)	20*** (17, 24)	4.3** (1.2, 7.4)	7.8*** (5.4, 10)	6.3*** (3.2, 9.5)

1. All columns describing patient positioning sum to Cases by row and Total by column
2. Includes lateral (right or left), head elevated (immobilized), Trendelenburg, and not specified
3. Collar-only column applies to the period after protocol change, April 2016. Cases are the sum of collar-only (as listed) and board-and-collar (not shown). Cases in 2016 after protocol change: 1251

*P values: * < 0.05, ** < 0.01, *** < 0.001*

Consistent with international guidelines,[2,45] cases of isolated penetrating trauma were exempted from treatment in 2014. Treatment in these cases was low prior to protocol change, partly because these patients are often critically injured and prehospital spinal protocols prioritize immediate treatment and transport of threats to life over taking time to apply spinal precautions. During the study period, the rate of treatment in these cases decreased from 17% (2009) to 4.7% (2020), an average annual rate of -12% per year (95% CI: -15%, -8.7%).

Table 1.5 presents associations between key treatment practices and patient characteristics. Collar-only treatment (compared to treatment with a backboard and collar) was significantly associated with low acuity cases: odds ratio (OR) 3.01 (95% CI: 2.64, 3.43). Assaults (as compared to MVAs) were also significantly more likely to be treated with a collar only (OR 3.07 [95% CI: 2.49, 3.79]). Conversely, pediatric patients had significantly lower odds of being treated with only a cervical collar as compared to a backboard (OR 0.26 [95% CI: 0.20, 0.33]), as were sports-related MOIs and all indications (except for intoxication). Characteristics related to positioning other than supine follow the same pattern as collar-only treatment, although sports-related MOIs and findings of head trauma and distracting injury had no significant associations. The use of a "no-neck" collar was significantly associated both an age over 65 (OR: 1.24 95% CI: 1.14, 1.36]) and female patients: OR 1.25 (95% CI: 1.17, 1.32). "No-necks" were less likely to be used in MOIs marked "Not reported / other", but not in any other mechanism (all in comparison to MVAs). Their use was associated with findings of a decreased level of consciousness, intoxication, and spine tenderness.

Table 1.5: Associations between treatment and patient characteristics in prehospital patients treated with spinal precautions

	Collar only, ref. backboard (2016 – 2020)		Other positioning, ref. supine (2016 – 2020)		Collar size "no-neck", ref. all others (2009 – 2020)	
	Estimate (SE)	OR (95% CI)	Estimate (SE)	OR (95% CI)	Estimate (SE)	OR (95% CI)
Age (ref. adult 17-65)						
Pediatric (<17)	-1.36 (0.13)	0.26*** (0.20, 0.33)	-0.90 (0.15)	0.41*** (0.30, 0.55)	N/A	N/A
Geriatric (>65)	-0.14 (0.08)	0.87 (0.75, 1.02)	0.07 (0.08)	1.07 (0.90, 1.26)	0.22 (0.05)	1.24*** (1.14, 1.36)
Sex (female, ref. male)	-0.01 (0.06)	0.99 (0.88, 1.11)	-0.04 (0.06)	0.96 (0.85, 1.08)	0.22 (0.03)	1.25*** (1.17, 1.32)
Acuity (low, ref. high)	1.1 (0.07)	3.01*** (2.64, 3.43)	1.01 (0.08)	2.74*** (2.35, 3.20)	-0.07 (0.04)	0.93 (0.86, 1.01)
MOI (ref. MVA)						
Assault	1.12 (0.11)	3.07*** (2.49, 3.79)	0.52 (0.11)	1.69*** (1.37, 2.08)	0.01 (0.05)	1.01 (0.91, 1.13)
Fall	0.02 (0.09)	1.02 (0.86, 1.21)	-0.08 (0.1)	0.92 (0.76, 1.12)	0.05 (0.05)	1.05 (0.96, 1.15)
Sports-related	-0.70 (0.25)	0.50** (0.30, 0.80)	-0.49 (0.29)	0.61 (0.34, 1.05)	-0.16 (0.11)	0.85 (0.69, 1.06)
Not reported / other	0.41 (0.07)	1.5*** (1.3, 1.74)	0.18 (0.08)	1.19* (1.02, 1.4)	-0.15 (0.04)	0.86*** (0.79, 0.93)
Indications (present, ref. absent)						
GCS < 15	-0.72 (0.06)	0.49*** (0.43, 0.55)	-0.29 (0.07)	0.75*** (0.65, 0.85)	0.19 (0.04)	1.21*** (1.13, 1.30)
Head trauma	0.12 (0.06)	1.13* (1.00, 1.28)	0.11 (0.07)	1.11 (0.98, 1.26)	0.03 (0.03)	1.03 (0.96, 1.10)
Intoxication	0.07 (0.07)	1.07 (0.94, 1.22)	-0.09 (0.07)	0.91 (0.80, 1.05)	0.19 (0.04)	1.21*** (1.13, 1.30)
Distracting injury	-0.35 (0.07)	0.70*** (0.62, 0.80)	0.00 (0.07)	1.00 (0.87, 1.15)	-0.01 (0.03)	0.99 (0.92, 1.06)
Spine Tenderness	-0.28 (0.06)	0.76*** (0.67, 0.85)	-0.23 (0.06)	0.80*** (0.70, 0.90)	0.17 (0.03)	1.19*** (1.12, 1.27)
Neurologic deficit	-0.75 (0.13)	0.47*** (0.37, 0.61)	-0.43 (0.15)	0.65** (0.48, 0.86)	-0.04 (0.06)	0.96 (0.85, 1.08)

*P values: * < 0.05, ** < 0.01, *** < 0.001*
Ref., reference; SE, standard error; OR, odds ratio; MOI, mechanism of injury; MVA, motor vehicle accident; GCS, Glasgow Coma Scale

DISCUSSION

This study summarizes patterns of prehospital care for potential spine injuries in one EMS agency during a period of practice change. Most notably, the data presented here demonstrate a significantly decreasing rate of treatment, with an apparent floor effect over the final third of the study period (Figure 1.2, Table 1.1). More detailed descriptions of patient and practice characteristics also reveal changing patterns over time. The rising proportion of high acuity patients shows that the decrease in treatment has not been applied evenly, but more so to less seriously injured patients (Table 1.2). Although overall treatment has been decreasing, collar-only use has risen every year since it became an option (Table 1.4). Patient positioning has followed the same trend, with continuing increases in options other than supine (despite supine being mandated). Finally, the pattern of cervical-collar sizing scene in these data (while not checked against neck sizes in the population) departs from what might be expected based on guidelines (Table 1.3).

Although there is sparse literature describing prehospital treatment of potential spine injuries, two studies provide some points of comparison. A large retrospective cohort study of data from Australia documents over 100,000 patients identified as at risk for spine injury (though not all treated with spinal precautions) from 2007 through 2012.[25] The patient group in that study was slightly older (median age, 51), with a lower proportion of males (52.2%), and a much higher proportion of women over 65 (23.6%) compared to the current data.[25] While 48.8% are described as meeting major trauma guidelines, study results show that 34.3% were transported to a major trauma or spinal center – a figure that approximates the proportion of high-acuity patients in this data. Falls were the most common MOI listed (46.9%), followed by traffic accidents (39.4%); “violence” accounted for 6.7% of cases (whereas assaults made up 15% in the current results). Among the listed MOIs, falls increased in frequency, from 1,033 in 2007 to 2,623 per million per year in 2012.[25] A similar study from the Netherlands described all patients treated with spinal precautions between 2008 and 2013.[26] Out of a total of 1082 patients, that study reported a mean age of 43 (SD, 18.3), 59% male, with 14% over the age of 65 – results similar to those found here. A high proportion (69.7%) of MOIs were not reported. Among the included patients, 15.8% received non-standard treatment according to applicable guidelines, including 5.1% treated with only a cervical collar. When present, reasons for deviation related to attempts to adapt treatment to the patients' injuries or underlying conditions.[26] Although both studies provide some comparisons for overall patient and practice characteristics, neither these nor others have investigated similar data for patterns of care over the timeframe of protocol changes.

What explains the patterns of treatment observed in these results? While the beginning of the study period follows the adoption of a selective immobilization protocol, that alone would not be responsible for a steady and continuing decrease over the course of years (similar protocols have been implemented and evaluated after brief training sessions[46-48]). And, although the study straddles the transition from SI to SMR, a change in treatment options would not be expected to affect the number of people who received some form of treatment. Similarly, we might expect the use of collar-only treatment to have increased gradually over time after the implementation of new treatment options – but not for years. Rates for wound care and splinting within the same service show no similar pattern, ruling out a general decrease in all trauma treatments. The practice variety observed in these results exceeds what might be expected by protocol changes alone.

It is possible the observed decrease in treatment reflects a shift in attitudes among frontline providers. As the standard of care has evolved from uniform treatment for any patient with any possibility of injury towards a more stratified approach, practitioners have likely become less rigid in their application and interpretation of written guidelines. In this view, although the indications for treatment have not changed, the interpretation of which MOIs are sufficient to cause an injury (or one with the potential for neurologic deterioration) have. A small number of studies examining the attitudes of EMS personnel towards spinal precautions supports this interpretation. Research conducted before widespread SMR changes found that prehospital providers felt that SI was too frequently applied, and that those with ALS qualifications in particular viewed it as often redundant or not helpful in certain cases.[13,49,50] The few published studies that have surveyed providers on changing standards have documented support for evolving guidelines and enthusiasm for moving beyond strict requirements and towards flexible approaches.[13,51] Respondents to a recent survey within this service have documented a belief that SMR is seen as less important than in the past, as well as some skepticism towards the effectiveness, importance, and applicability of SMR.[52] Participants noted the discomfort that standard spinal precautions causes patients and reported consciously choosing smaller collars or alternative positioning to avoid aggravating patients, choices that reflect an underlying tension between balancing the need to adhere to protocols with that of providing care to diverse patients in unpredictable situations.[52] The data collected in this study illustrate these patterns. The significant increase in the proportion of high-acuity patients implies that patients with minor injuries or low-risk MOIs have received spinal precautions less frequently over time. Among patients who are treated, low-acuity and assaulted patients are more likely to receive treatment with a collar only and alternative positioning, and elderly patients and female patients are both more likely to receive a “no-neck” cervical collar (Table 1.5). Reported reasons for non-standard treatment from prior literature also reflect adaptations based on circumstance.[26]

To the extent that the attitudes of providers during a time of change affect treatment decisions, the results of this study are relevant to the prehospital treatment of potential spine injuries in general. The available studies on provider attitudes, while limited, signal diverse and strong views to both past practice and new standards.[13,49,50] SMR principles have been widely adopted across jurisdictions,[3,4,53,54] and it is unlikely that documented attitudes are isolated to services that have published research, or that changing patterns of treatment will not be found elsewhere. The possibility of inconsistent care raises patient- and system-oriented questions that deserve investigation. Are patients with injuries not receiving spinal precautions? Decreasing rates of treatment, where they exist, should be compared against outcomes at the level of individual patients to examine the possibility of missed injuries. Are patients, whether treated or not, experiencing harm? It is equally possible that changing rates of treatment reduce over-treatment of the non-injured without compromising patient safety. This scenario, which would continue a shift away from widespread SI, might reflect a silent and uncoordinated compensation for previous “surplus safety” described in other areas.[55] Finally, if changes in patterns of care are influenced by factors beyond protocols and guidelines, how do these changes propagate throughout a service? These data show that a change in documentation was associated with a brief but significant increase in treatment before returning to an underlying trend (Figure 1.2, Table 1.1). Future research might investigate this and other ways that provider attitudes, team dynamics, and service characteristics influence decision-making and the application of clinical decision rules in an environment that has been described as non-linear, complex, and dynamic.[56-59]

LIMITATIONS

A number of limitations apply to this study beyond those associated with a retrospective, observational design. Practice standards around SMR vary by jurisdiction, and not all practices described here will be relevant in other areas. Although overall data missingness was very low, a high proportion of cases did not report the MOI, limiting the interpretation of these findings. These data relate only to cases of treatment with spinal precautions; no data were collected on either trauma patients who were not treated (whether high- or low-acuity) or patients later diagnosed with traumatic spine injuries. Both of these groups would provide important complementary information about SMR practices and the accuracy of prehospital identification of injuries. Finally, these findings should be interpreted in the context of the base of evidence for SMR in general. The benefits and harms of spinal precautions have not been formally quantified in randomized clinical trials, and specific practices are not supported by high-level evidence. Current and future studies aiming to improve emergency treatment of potential spine injuries must address a range of inherent limitations in applying available evidence to practice.

CONCLUSIONS

This study describes a decreasing trend in spinal precautions treatment and evolving patient and practice characteristics in one North American EMS agency. These patterns of care cannot be attributed solely to formal protocol changes. Similar patterns and their possible explanations should be investigated elsewhere; in this service, ongoing research will relate these findings to patient outcomes. The optimization of the treatment for potential spine injuries will depend on future studies that not only account for previously unmeasured influences on practice but also consider how guidelines are implemented and followed in frontline settings.

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Paramedic attitudes towards prehospital spinal care: a cross-sectional survey

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ABSTRACT

Background The optimal application of spinal motion restriction (SMR) in the prehospital setting continues to be debated. Few studies have examined how changing guidelines have been received and interpreted by emergency medical services (EMS) personnel. This study surveys paramedics' attitudes, observations, and self-reported practices around the treatment of potential spine injuries in the prehospital setting.

Methods This was a cross-sectional survey of a North American EMS agency. After development and piloting, the final version of the survey contained four sections covering attitudes towards 1) general practice, 2) specific techniques, 3) assessment protocols, and 4) mechanisms of injury (MOI). Questions used Likert-scale, multiple-choice, yes/no, and free-text responses. Exploratory factor analysis (EFA) was used to identify latent constructs within responses, and factor scores were analyzed by ordinal logistic regression for associations with demographic characteristics (including qualification level, gender, and years of experience). MOI evaluations were assessed for inter-rater reliability (Fleiss' kappa). Inductive qualitative content analysis, following Elo & Kyngäs (2008), was used to examine free-text responses.

Results 220 responses were received (36% of staff). Raw results indicated that respondents felt that SMR was seen as less important than in the past, that they were treating fewer patients than previously, and that they follow protocol in most situations. The EFA identified two factors: one (Judging MOIs) captured paramedics' estimation that the presented MOI could potentially cause a spine injury, and another (Treatment Value) reflected respondents' composite view of the effectiveness, importance, and applicability of SMR. Respondents with advanced life support (ALS) qualification were more likely to be skeptical of the value of SMR compared to those at the basic life support (BLS) level (OR: 2.40, 95%CI: 1.21-4.76, p=0.01). Overall, respondents showed fair agreement in the evaluation of MOIs (k=0.31, 95%CI: 0.09-0.49). Content analysis identified tension expressed by respondents between SMR-as-directed and SMR-as-applied.

Conclusion Results of this survey show that EMS personnel are skeptical of many elements of SMR but use various strategies to balance protocol adherence with optimizing patient care. While identifying several areas for future research, these findings argue for incorporating provider feedback and judgement into future guideline revision.

Keywords emergency medical services; paramedic; prehospital; spinal injuries; survey

BACKGROUND

Major changes over the last decade in the standard of care for treating potential spine injuries in the prehospital setting have been described as a paradigm shift.[1] These changes have occurred across international jurisdictions, and new options for treatment allow greater flexibility than previous guidelines.[2-6] However, although the general principle of reducing movement has been widely endorsed, prehospital treatment recommendations falling under the heading of spinal motion restriction (SMR) still show significant differences. Some, for example, recommend the cervical collar as a critical component of care[7]; others recommend against it, propose a soft (as opposed to rigid) alternative, or forego its use in some situations.[8-12] This and similar questions continue to be debated.[13-15]

Few studies have examined how emergency medical services (EMS) personnel have responded to these changes. A recent survey from Norway evaluated the use of a new national prehospital spinal treatment guideline, but was focused on implementation, not attitudes towards practice.[16] Other available research shows that emergency medical technicians (EMTs) in the

United States believed that the prior practice of spinal immobilization (SI) was generally over-used, and that those with advanced life support (ALS) qualifications in particular viewed it as often unnecessary or not optimal in certain cases.[1,17,18] Limited research on SMR across countries demonstrates that EMTs and paramedics feel empowered and positive towards what are seen as progressive advances.[1,11]

In the context of evolving guidelines and limited information on provider attitudes, documented practice appears to vary more than might be explained by protocol changes. One study, focusing on geriatric patients with confirmed spinal injuries within a single service, reported that the number of patients who received no prehospital SMR rose from 15.5% to 31.6% after the transition to SMR protocols.[19] Another, assessing the shift to soft-collar use in emergency departments (in areas where local EMS used rigid collars), observed that up to one-third of trauma patients met criteria for spinal precautions but received none of any kind in both the hospital and prehospital settings.[20] Auditing the implementation of a prehospital selective immobilization protocol, Domeier *et. al.* found substantial lack of agreement among practitioners in the estimation of trauma with the potential to cause a spine injury.[21] This study concluded that up to 25% of patients did not receive an assessment in cases where the authors judged that the mechanism of injury (MOI) should clearly or possibly have triggered one. Other studies have documented rates of under- and over-treatment compared to assessment results ranging from 5% to 29%.[22-24]

There is growing recognition that prehospital guidelines require the input and feedback from end users to ensure their applicability.[25] This work is informed by research into decision-making by EMS personnel and the role of clinical decision rules in prehospital and emergency settings.[26-30] As spinal-treatment guidelines continue to evolve, knowledge of how protocols are interpreted and applied in the field will be required to optimize patient care. Despite the relevance of best practices in trauma care across international jurisdictions, this area has received little attention. No study has used multiple methods to explore beliefs of EMS personnel around current procedures in the context of an evolving standard for spinal care. To fill this gap, this study surveys paramedics' attitudes, observations, and self-reported practices around the treatment of potential spine injuries in the prehospital setting. In addition to describing survey findings, it specifically aims to analyze response data for latent constructs and insights, associations among results and provider characteristics, and provider agreement in areas of practice drawn from prior research.

METHODS

Reporting of this study conforms to the "Checklist for Reporting Of Survey Studies" (CROSS) guideline.[31]

This was a cross-sectional survey of a single EMS agency located in central Canada. A draft survey was developed in consultation with local practitioners (n=16) using a Delphi process modified to start with candidate questions informed by existing studies.[32,33] This version was tested on a sample of EMS personnel at an international paramedic conference (n=39). This process informed revisions to the final version, available as Appendix 2.1, "Final survey". The survey was organized in four sections:

1. Attitudes towards practice in general (nine questions, including six Likert-scale, two multiple-choice with free-text options, and one free-text)
2. Attitudes towards specific techniques and practices (13 questions, including 10 Likert-scale and three multiple-choice, one with a free-text options)

3. Attitudes towards spinal assessment protocols (six questions, including four Likert-scale and two multiple-choice with free-text options)
4. Judging MOIs (13 questions, including 12 yes/no choices and one multiple-choice with a free-text option)

This survey was disseminated within the Winnipeg Fire Paramedic Service (WFPS) in Winnipeg, Manitoba, Canada, with the cooperation of senior leadership and labour groups. No one outside the study team and development process had input into survey content. The WFPS responds to all 911 activations within a city of approximately 750,000. Using a tiered response model, it handles over 80,000 medical calls per year with basic life support (BLS) first response, and mixed BLS and advanced life support (ALS) transport. In common with many similar agencies, the WFPS has made several revisions to guidelines for the treatment of potential spine injuries. Most notably, it implemented a selective immobilization protocol based on the NEXUS criteria and other prehospital algorithms in March 2009.[21,34,35] As well, it adopted SMR treatment options in April 2016, which allowed for treatment with only a cervical collar in low-risk cases (as defined by patients who were ambulatory prior to EMS arrival).[36]

The survey was open to all licensed BLS and ALS providers within the service (n=615 at the time of the survey, all of whom are termed “paramedics” under national certification guidelines). The survey was hosted on a commercial online platform (SurveyMonkey Inc, San Meteo, CA, www.surveymonkey.com). Information about the survey was distributed via memos and posters within the workplace; participation was anonymous and multiple responses were disabled by the survey platform. The target sample size was set at 200 to reflect a suggested minimum (n=180, plus leeway for missing data) for exploratory factor analysis (EFA) with a survey of this structure.[37] The survey period started in December 2020, and a participation reminder was sent after one month; it was closed in April 2021 after reaching the target sample size. Distribution of the survey was approved by the University of Manitoba Health Research Ethics Board, HS22960 (H2019:252).

Data analysis

Exploratory Factor Analysis

Although this survey was organized in sections that reflect topic areas drawn from prior research, it is unknown whether these correspond to how paramedics conceive the subject. In the absence of any previously validated survey instrument or established knowledge domains, EFA was conducted to identify potential latent constructs related to paramedic attitudes towards spinal care. Principal axis factoring and oblique rotation (direct oblimin) were used to identify factors. Extraction was determined by Cattell's criterion (excluding the inflection point on the graph of eigenvalues). Factor loadings above 0.3 were included to set a low threshold for identifying contributing variables. On analysis, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.65, and Bartlett's test of sphericity was significant at <0.0001, $x^2(190)=685.7$. Summed factor scores were described for all participants by median, interquartile range (IQR), and range. Among identified factors, included variables were assessed for internal consistency using McDonald's omega.[38]

Demographic characteristics

A cumulative-odds ordinal logistic regression with proportional odds was run to determine the effect of demographic characteristics on factor scores. Characteristics included qualification level (ALS versus BLS), years of experience (greater than versus less than or equal to 10 years), and gender (woman versus man). The covariate, years of experience, was included to reflect the common finding that experience influences practitioners' decision making[26-28]; the threshold of 10 years was informed by pilot results that demonstrated higher levels of participation among very experienced providers. To facilitate analysis, factor scores were partitioned into three, four, and five levels and tested for model fit. Based on these results, the final analysis used three levels for Judging MOIs and four levels for Treatment Value. Given the exploratory approach to the analysis, all Likert-scale questions included in the EFA but not contained within identified factors were analyzed on an individual basis by the same method using the levels from the question. Results for those questions with significant model fit are reported.

Inter-rater reliability of judging traumatic mechanisms of injury

Section 4 of the survey provided example MOIs and asked paramedics to categorize them as either having or not having potential to cause a spine injury. This choice reflects the decision point determining entry into prehospital selective treatment protocols, whether assumed or explicitly stated.[35] The wording in the survey mirrors the specific documentation requirements of the service. Inter-rater reliability was assessed with Fleiss' kappa and applied overall, within demographic sub-groups identified above, and among groups of scenarios related by patient (geriatrics, pediatrics) or MOI type (falls, assaults, motor vehicle crashes [MVCs]).[39] Two MOIs were included as calibration questions, with scenarios meant to be unambiguously positive or negative. In these questions, respondents showed near perfect agreement ($k = 0.99$).

All analysis was conducted in SPSS, version 28.0.1 (IBM Corporation; Armonk, New York USA) or R, version 4.0.5 (Foundation for Statistical Computing; Vienna, Austria). A threshold of alpha <0.05 was considered statistically significant.

Content Analysis

Seven questions in the survey allowed free-text responses. With no recent investigations of paramedics' attitudes in this area, inductive qualitative content analysis was chosen as appropriate to explore and describe the phenomenon.[40] The analysis followed the process outlined by Elo and Kyngäs (2008) and informed by more recent methodological guidance.[41,42] After preparation and in the process of de-contextualization, all responses were condensed and coded by two authors independently (NM, RP); during re-contextualization, codes were collected and inductively abstracted into sub-categories by both authors independently and then compared. Continuing abstraction occurred through discussion, during which both authors worked towards consensus by mutual questioning and reflection, iteratively reviewing and comparing the data and categories and maintaining congruence between levels of abstraction and degrees of interpretation.[43,44] Results were discussed and reviewed with the third author.[44] The findings of the analysis describe the manifest content of the data with a low level of interpretation and high level of abstraction.[42,43]

Raw and missing data

Responses were received from 220 paramedics. This represents 36% of eligible staff, including those on leave. Raw data from Likert-scale and multiple-choice questions are presented in Appendix 2.2, "Raw survey data". Appendix 2.3, "Free-text responses", outlines free-text responses and corresponding sub-categories (with illustrative quotations) by each question. Notable findings from the undifferentiated data will be reported in the results.

Of 220 responses received, 179 completed all questions used in the quantitative analyses. Of the remaining 41, 23 were excluded outright because there were no responses beyond the initial demographics. Of the final 18, nine omitted all questions in section 4, related to MOI. Therefore, all analyses involving section 4 used 188 cases; remaining analyses used 197. Among these, there were 40 missing values (0.85% of the total); variable means (for continuous variables) or modes (for ordinal and categorical variables) were imputed in these cases.

RESULTS

Table 2.1 shows the demographic breakdown of the 197 respondents included in the main analysis.

Table 2.1: Characteristics of participants in a paramedic survey of spinal care

Characteristic	Number of respondents (percent)	Number in department (percent)
Qualification Level		
BLS	105 (53)	449 (73)
ALS	92 (47)	166 (27)
Gender		
Woman	62 (31)	133 (22)
Man	134 (68)	482 (78)
Transgender	0	-
Non-binary/non-conforming	0	-
Prefer not to respond	1 (0.5)	-
Years of practice		
<=10	89 (45)	-
>10	108 (55)	-
Age		
20-29	33 (17)	-
30-39	91 (46)	-
40-49	56 (28)	-
50-60	17 (9)	-

BLS, basic life support; *ALS,* advanced life support

Of note among the overall results, 70% of respondents felt they were treating “many” or “somewhat” fewer patients than in the past (question 1.7), a result mirrored by 71% who indicated that SMR is seen as “much” or “somewhat” less important than previously (question 1.8). A majority (74%) stated they apply the smallest available cervical collar most often (question 2.4). When asked whether they would either use precautions when not indicated by protocol (question 3.3) or not use them when they were indicated (question 3.5), majorities in both cases indicated “infrequently” or “never” (93% and 95%, respectively).

Exploratory Factor Analysis

Two factors were identified during the EFA. Table 2.2 lists the items included in each factor, and Table 2.3 details factor eigenvalues, percent variance explained, and internal consistency. The first factor, labelled Judging MOIs, captures paramedics' estimation that the presented MOI could potentially cause a spine injury. The score scale runs from 0 to 9, where high scores reflect more MOIs judged to have injury potential, and lower scores fewer. Among all respondents, the median factor score was 6 (IQR: 4-7, range 0-9). The second identified factor, termed Treatment Value, reflects respondents' composite view of the effectiveness, importance, and applicability of SMR. Due to the scoring direction of individual questions, its maximum possible score (40) would indicate a high level of skepticism toward the value of treatment (or low level of endorsement), while the minimum (8) would indicate a low level of skepticism (or high level of endorsement). Overall, the median factor score was 26 (IQR: 24-29.75, range 19-37). Internal consistency of each factor was high (Judging MOIs, 0.77 and Treatment Value, 0.76). Item-drop and item-rest statistics were calculated for individual questions; item-rest correlations ranged from 0.31 – 0.58 and 0.23 – 0.61, for Judging MOIs and Treatment Value, respectively.

Table 2.2: Items included in factors identified by exploratory factor analysis in a paramedic spine survey

Factor 1: Judging MOIs

Question	Text (Yes/No response: Does this MOI have the potential to cause a spine injury?)	Factor loading[1]
4.7	Elderly adult (>65). Fall from standing. Laceration to the face. No loss of consciousness.	0.68
4.3	Adult, assaulted. Punched in the face. No weapons used. Fell to the ground.	0.68
4.8	Elderly adult (>65), assaulted. Punched in the face. No weapons. Fell to the ground.	0.64
4.11	Elderly adult (>65). Syncopal episode. Fall from standing.	0.64
4.5	Adult, tripped coming down stairs. Fell to the ground from one step.	0.59
4.6	Adult, fall from standing. Laceration to the face. No loss of consciousness.	0.54
4.12	Child (8 years old), fall from a slide onto grass, 2 meters. Hit head. Unknown if there was a loss of consciousness.	0.43
4.1	Child (7 years old), restrained on a booster seat on the driver's side, rear. MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.	0.42
4.9	Adult, restrained driver, MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.	0.40

Factor 2: Treatment Value

Question	Text (Likert-scale response)	Factor loading[1]
1.2	In your estimation, how often have you observed SMR ineffectively limit motion or cause more motion than no treatment or alternatives?	0.75
2.3	Among patients at risk for spine injury and in a cervical collar, how often do you observe patient movement that you feel could potentially cause further harm to their spine?	0.74
2.2	How often have you observed complications of a cervical collar resulting in more patient movement than no treatment or alternative / improvised treatment.	0.67
1.1	In your opinion, how effectively does SMR as currently practiced limit patient motion?	0.67
1.3	Among patients at risk for spine injury and in SMR, how often do you observe patient motion that you feel could potentially cause further harm to their spine?	0.67
2.1	In your opinion, how effectively does a cervical collar restrict head motion in a potentially spine-injured patient?	0.51
1.8	Do you feel SMR is seen as less or more important than it was in the past?	0.38
3.2	In general and in your opinion, would you rate your service's criteria for determining the need for spinal precaution as not restrictive enough (patients left untreated who need it) or too restrictive (too many patients treated who do not need it)?	0.38

Questions not included in factors: 1.4, 1.7, 2.5, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 3.1, 3.3, 3.5, 4.4

1. Factor loadings > 0.3 reported in descending order

MOI, mechanism of injury; *MVC,* motor vehicle crash; *SMR,* spinal motion restriction

Table 2.3: Characteristics of factors identified by exploratory factor analysis in a paramedic spine survey

	Factor 1: Judging MOIs	Factor 2: Treatment Value
Eigenvalue	3.53	3.28
Percent variance explained	12	11
Internal consistency[1]	0.77	0.76

1. McDonald's Omega

Demographic characteristics

Table 2.4a presents the association of qualification level, years of experience, and gender with factor scores using ordinal logistic regression. ALS providers were significantly more likely to be more skeptical of treatment value than their BLS counterparts (OR 2.40, 95%CI: 1.21-4.76, p=0.01), while men were less so than women (OR 0.53, 95%CI: 0.28-0.99, p=0.05). Experience was not significantly associated with Treatment Value factor scores, and no demographic characteristic was associated with MOI factor scores.

Questions with unique response patterns not included in identified factors were also analyzed in terms of demographic characteristics. Table 2.4b reports this analysis for the two questions whose overall model significantly predicted the dependent variable as compared to the intercept-only version. In question 2.7, ALS providers were significantly less likely to treat patients with isolated penetrating trauma than BLS providers, in accordance with local protocol (OR 0.10, 95% CI: 0.05-0.21, p<0.001). In contrast, those with greater than 10 years of experience were more likely to say they would (OR 2.65, 95% CI: 1.41-4.99, p=0.003). In question 1.7, ALS providers were much more likely than BLS to report the perception of treating fewer patients over time (OR 2.93, 95% CI: 1.58-5.43, p<0.001). This result does not appear to reflect longer experience, as no association exists between rates of treatment and those with more than 10 years practice as compared to fewer (OR 1.33, 95% CI: 0.74-2.41, p=0.3).

Table 2.4a

Qualification level, experience, and gender as predictors of factor scores[1]

Characteristic	Factor score - comparison	Factor score - reference	OR (95% CI)	p
Factor 1: Judging MOIs (do the presented MOIs have the potential to cause a spine injury?)				
ALS (ref BLS)	6 (4-7)	5 (3.5-7)	0.79 (0.40 - 1.54)	0.5
>10 years exp. (ref <=10 years)	6 (4-9)	5 (3-7)	1.72 (0.87 - 3.39)	0.1
Men (ref Women)	5 (3-7)	6 (4-7)	0.74 (0.41 - 1.34)	0.3

Scoring range, direction: 0 (fewer with potential) - 9 (more with potential)

OR > 1 means more likely to judge MOIs as potentially causing injury

Likelihood ratio test (full model compared to intercept-only), $x^2(3) = 3.52$, p = 0.3

Characteristic	Factor score - comparison	Factor score - reference	OR (95% CI)	p
Factor 2: Treatment Value (composite view of the value of SMR)				
ALS (ref BLS)	26.5 (24-29)	25 (22-27)	2.40 (1.21 - 4.76)	0.01
>10 years exp. (ref <=10 years)	26 (23-37)	25 (22-28)	1.25 (0.64 - 2.45)	0.5
Men (ref Women)	25 (22-28)	26 (24-29.75)	0.53 (0.28 - 0.99)	0.05

Scoring range and direction: 8 (less skeptical) - 40 (more skeptical)

OR > 1 means more likely to have a higher score

Likelihood ratio test (full model compared to intercept-only), $x^2(3) = 15.84$, p = 0.001

Table 2.4b

Qualification level, experience, and gender as predictors of question scores[1]

Characteristic	Question score - comparison	Question score - reference	OR (95% CI)	p
2.7 When treating a patient with isolated penetrating trauma to the head, neck, or torso, how often do you apply spinal precautions?				
ALS (ref BLS)	2 (1-2)	3 (2-4)	0.10 (0.05 - 0.21)	<.001
>10 years exp. (ref <=10 years)	2 (1-5)	3 (1-4)	2.65 (1.41 - 4.99)	0.003
Men (ref Women)	2 (1-4)	2 (1.25-3)	0.96 (0.56 - 1.66)	0.9

Scoring direction: 1 (less often) - 5 (more often)

OR > 1 means more likely to have a higher score

Likelihood ratio test (full model compared to intercept-only), $x^2(3) = 48.1$, p < 0.001

Characteristic	Question score - comparison	Question score - reference	OR (95% CI)	p
1.7 Do you feel you have been treating more or fewer patients with SMR over during your time in EMS?				
ALS (ref BLS)	4 (4-5)	4 (3-4)	2.93 (1.58 - 5.43)	<.001
>10 years exp. (ref <=10 years)	4 (4-5)	4 (3-4)	1.33 (0.74 - 2.41)	0.3
Men (ref Women)	4 (3-4.5)	4 (3-4)	1.16 (0.66 - 2.05)	0.6

Scoring direction: 1 (more) - 5 (fewer)

OR > 1 means more likely to have a higher score

Likelihood ratio test (full model compared to intercept-only), $x^2(3) = 21.0$, p < 0.001

1. All scores expressed as median (interquartile range)

OR, odds ratio; *MOI,* mechanism of injury; *ALS,* advanced life support; *BLS,* basic life support; *SMR,* spinal motion restriction

Inter-rater reliability of judging traumatic MOIs

Section 4 of the survey evaluated participants' agreement on categorizing a traumatic MOI as having the potential to cause a spine injury or not. Respondents showed fair agreement overall: k = 0.31 (95%CI: 0.08-0.48). Table 2.5 details agreement among each demographic sub-group and among all participants when evaluating particular patient groups and MOI types. While agreement among sub-groups was similar, all respondents showed higher agreement in evaluating scenarios related to low-level falls (k = 0.43, 95%CI: 0.04-0.68). In contrast, agreement was no better than chance on questions related to geriatrics, pediatrics, assaults, and MVCs.

Table 2.5: Inter-rater reliability of evaluations of mechanisms of injury in a paramedic spine survey

Group	Fleiss' kappa (95% CI)
All raters, all questions	0.31 (0.09 - 0.49)
Demographic trait	
ALS	0.31 (0.08 - 0.51)
BLS	0.31 (0.10 - 0.47)
>10 years' experience	0.31 (0.09 - 0.49)
<= 10 years' experience	0.31 (0.12 - 0.47)
Men	0.31 (0.09 - 0.49)
Women	0.34 (0.07 - 0.51)
MOI type	
Geriatrics	0.03 (-0.01 - 0.05)
Pediatrics	0.03 (-0.01 - 0.03)
Assaults	0.04 (-0.01 - 0.04)
MVCs	-0.01 (-0.02 - 0.01)
Falls	0.43 (0.04 - 0.68)

ALS, advanced life support; *BLS,* basic life support; *MOI,* mechanism of injury; *MVC,* motor vehicle crash

Content analysis

Table 2.6 displays the category map of free-text responses to seven open-ended questions.[41] (Appendix 2.3 lists sub-categories by question.) A common thread evident among all responses was abstracted as a main category: tension between SMR-as-directed and SMR-as-applied. This main category captures the competing imperatives of working within and according to protocol while at the same time recognizing the limitations of SMR and adapting treatment on a patient-by-patient basis to optimize care – adaptations that sometimes step outside or work at the edges of written guidelines. Two categories support and provide more detailed descriptions of this sentiment.

The first category encompasses complications and solutions in the application of SMR. This category includes observations that SMR sometimes causes motion and knowledge of its adverse effects, as well as work-arounds and suggestions for improvement. Respondents frequently described SMR as less than effective, observing that that treatment devices aggravate almost all patients, and especially those who are anxious or agitated. One response describes this scenario and provides a justification for not treating a patient altogether:

> *I've grown tired of fighting with people who are intoxicated, combative, etc., and ... think I can make a case that not wrestling with someone and allowing them to not be immobilized is safer for them than wrestling with someone I suspect is truly injured.*

Also citing the adverse effects of treatment, responses detailed additional strategies to minimize movement. These included consciously under-sizing cervical collars, allowing alternative positioning, and (in two cases) not treating when indicated by protocol. Suggested improvements included using a soft cervical collar (as opposed to rigid), allowing patients to self-extricate from vehicles, options for sedation, removing the long backboard for transport, and the ability to identify low-risk patients as candidates for further assessment without applying any restraining devices.

The second category summarizes conflicting influences on how to apply SMR. On one hand, participants recognized that they follow their training and work according to protocols and written guidelines. Some observed that protocols had been updated, advanced education had improved their understanding, and more ongoing training would improve care. At the same time, participants outlined a variety of alternative, sometimes contradictory, influences on their practice. These include past experiences with challenging situations not imagined in guidelines, familiarity with recent research highlighting the limitations of SMR, and differing standards in other jurisdictions. Notably, some respondents described a silent evolution of workplace standards away from strict protocol adherence with possible punishment for deviation and towards a culture with less emphasis on SMR. Whereas the prior approach to potential spine injuries was characterized as “gross over-caution,” participants described unwritten “employer expectation changes” and “less fear in the workplace around disciplinary action towards not utilizing SMR” as contributors to an evolving standard.

Table 2.6: Inductive qualitative content analysis of free-text responses in a paramedic spine survey, with illustrative quotations

MAIN CATEGORY	TENSION BETWEEN SMR-AS-DIRECTED AND SMR-AS-APPLIED	
Categories	Complications and solutions in the application of SMR	Conflicting influences on how to apply SMR
Sub-categories	SMR causes motion Adverse effects of SMR Efforts to minimize patient movement Suggested improvements	Direction from protocols and guidelines Training in the procedure and higher education Past experience with difficult/unusual situations Knowledge of recent research Influence of workplace culture
Illustrative quotations	• *Patient discomfort with the c-collar seems lead to many cases of patients readjusting, pulling at, attempting to remove c-collar, leading to increased manipulation of the neck. [The] "no-neck" [smallest] size seems to help with patient comfort and reduce this.* • *I've grown tired of fighting with people who are intoxicated, combative, etc., and ... think I can make a case that not wrestling with someone and allowing them to not be immobilized is safer for them than wrestling with someone I suspect is truly injured.*	• *[Past practice] led to a vast number of unnecessarily boarded patients. Change in protocol and more leeway in critical decision-making during assessment led to improvement in this area.* • *More experience means comfort in defending/rationalizing my choice for SMR....Less willingness to treat in a certain way because "it's always been that way."* • *More research done showing many adverse effects.* • *[There is now] less fear in the workplace around disciplinary action towards not utilizing SMR.*

DISCUSSION

The results of this survey portray paramedic attitudes towards prehospital SMR as nuanced and complex. Although participants in this survey report that they generally follow relevant protocols, detailed responses illustrate many ways in which providers balance protocol adherence with attempts to optimize care. Most notably, responses demonstrate broad skepticism towards the value of SMR (raw data, Table 2.2). Particularly among ALS providers, rating responses and analyses indicate strongly that SMR is seen as less important than in the past and that they are treating fewer patients with SMR than before (Tables 2.4a & b). Free-text responses expand on these findings and provide specific examples of ways in which paramedics navigate the practice environment and resolve the tension that arises when protocolized treatment does not match the clinical situation (Table 2.6).

While drawn from a single service, these findings are relevant for the treatment of potential spine injuries in general. These results inform current techniques or raise key questions for future study in three specific topic areas, whatever the status of local protocols. These topic areas include the connection between provider attitudes and treatment patterns, the application of selective immobilization protocols, and the use of specific devices, particularly cervical collars. Additionally, these findings can be placed in a broader context of paramedic decision-making, where they support including frontline providers in the process of guideline development and implementation.

First, the connection between the views of frontline providers and patterns of treatment has not been widely researched. Some studies have reported feelings of skepticism towards the value of SI or SMR among EMS personnel in a variety of settings,[1,17,18] and others have described differences in treatment before and after the transition to SMR,[19,45] but the relationship between provider beliefs and treatment patterns deserves more exploration.[46] In the service being surveyed, there has been a decreasing trend in the number of treatments over the last decade.[47] It is not clear why SMR would be associated with fewer treatments or more missed injuries. One possible explanation is that SMR has done more than simply provide alternative assessment and treatment options: in considering the limitations of past practice, it has also shifted baseline assumptions of potential harms and benefits of treatment – implicitly granting permission for more widespread practice change. This view corresponds with earlier opinions of SI as over-used, un-necessary, or sub-optimal,[1,17,18] and respondents to this survey described exactly this shift in practice in terms of “less fear in the workplace…towards not utilizing SMR” and a move away from “gross over-treatment”. Whether this shift can be described as adequate correction or over-compensation remains to be seen. Further research should investigate patterns of care to determine not only trends in treatment but also clinical outcomes of patients with injuries who do not receive prehospital SMR at the local or individual level.

These survey results are also relevant for the use of selective immobilization protocols. A number of prior studies have documented the discrepancy between assessment findings and treatment provided, most often in the case of not applying devices when indicated.[20-22] While past research has noted substantial variation in how providers interpret MOIs,[21] and consequently whom they choose to assess, this area of decision-making has not been prospectively quantified. Section 4 of this survey was designed to assess exactly this. The results show that providers achieved only fair agreement on whether or not an MOI has the potential to cause a spine injury (Table 2.4). Although the magnitude of the kappa statistic can be affected by many factors and interpretations can be considered somewhat arbitrary,[48] it is not surprising that agreement among these MOIs, which were deliberately written to reflect marginal scenarios, appears relatively low. This finding serves as a reminder that spinal assessment protocols depend on a subjective decision to apply them, and, as prior research has shown, these decisions are both variable and clinically relevant for some groups. [21] While the risk of injury from a marginal MOI might be negligible for most patients, geriatrics appear to be over-represented among those with spine injuries and without prehospital treatment, often from scenarios thought to be low-risk.[22,49,50] Evaluations of assessment protocols should account for variation in how patients are identified as candidates and include an ability to audit cases where it was not applied.

The findings of this survey also relate to a third area of practice, the use of cervical collars. Within these results, 74% stated they apply a “no-neck” (the smallest among available sizes) most often, and 54% reported routinely measuring for collar size. Free-text responses commonly reported deliberately under-sizing collars to minimize patient discomfort and resulting movement. Neither self-reported collar-size distributions nor the rationale behind sizing choices made in the field has been described previously. In contrast, treatment guidelines that support collar use emphasize measuring and fitting the collar to the patient, using standard sizes that vary by millimeters.[4,7] One study tested providers on their ability to apply a collar to a mannequin and judged that only 11% of participants were able to do so correctly.[51] These sources appear to base their determination of what is correct and proper on manufacturers’ guidelines and a small number of laboratory and cadaver studies that have investigated sizing.[52-54] Although these studies show increased restriction with fitted devices, their methodologies have limited connection to field conditions and their findings cannot be generalized to patient care. In contrast to guidelines that emphasize the importance of properly fitted collars, an increasing number of position statements cite sparse evidence of benefit and recommend variations on no use, judicious use, or soft alternatives.[5,8-10,12] Additionally, one recent study involving actual trauma patients found that patient movement depended more on patient behavior than the device applied.[55] In this context, it would be possible to interpret these survey results not as a signal of protocol non-compliance, but as frontline providers working within local requirements to balance the benefits and harms of treatment for their patients. It is unknown whether this practice tendency is unique to this service, but in the absence of any demonstrated benefit to sizing collars among available options, the notion of a what constitutes a properly fitted collar should be reconsidered.

As illustrated by the variety of approaches to something as superficially simple as putting on a cervical collar, the application of written protocols to varied circumstances requires substantial judgement from providers. The role of judgement has been acknowledged and studied particularly in the context of trauma-alert protocols, finding it to be a major factor.[25,26] More detailed investigations of prehospital decision-making have consistently found that the process is not linear but complex and dynamic, and informed more by the experience, education, and tendencies of the provider than by written guidelines.[26-28] In both prehospital and emergency settings, protocols and clinical decision rules are seen to function as a cognitive scaffold and safety net for inexperienced providers instead of a practice template for all.[27,28,30] This understanding would see a gap between protocol and practice not as an issue of non-compliance or inadequate education, but as the inevitable result of applying linear tools to a complex, non-linear environment.[30] Although not previously applied to prehospital spinal care, this view provides a persuasive interpretative context for the attitudes and behaviors recorded in this study; it also supports the inclusion of provider judgement within treatment guidelines as well as end-user input into future revisions.[25]

LIMITATIONS

The results of this survey reflect the self-reported views of paramedics in one service at one time. It is unknown whether these results are generalizable to other services or other jurisdictions. Local SMR protocols vary, and not all questions and responses recorded here will be relevant to other agencies. Among the submitted surveys, not all were complete (although the number excluded was relatively small). Among survey respondents, ALS providers and women were both over-represented as compared to the composition of the service as a whole. As both differences were statistically significant (ALS: 47% versus 27%; difference: 20%, 95%CI: 12 to 28%; women: 31% versus 22%; difference: 9%, 95%CI: 2 to 17%), it's unlikely this pattern was entirely random. Non-random survey response could bias results. In this case, observed associations between ALS providers and women with factor scores might reflect this bias. It's possible that paramedics with strong views were more motivated to take the survey or to enter responses towards the extremes. Similarly, free-text responses might similarly be biased to highlight those with more developed and well-articulated opinions on the topic. The results of this survey should be interpreted in the context these possibilities. The influence of this pattern of expression on patient care is unknown.

CONCLUSION

This survey reports prehospital providers' beliefs, observations, and practices related to prehospital spinal care after the implementation of SMR. These results support continued research in several areas, including the assessment of treatment outcomes after SMR implementation, the application and execution of prehospital selective immobilization protocols, and the effectiveness of procedures and devices in field use. Although there is widespread agreement in the overall goal of reducing motion among potentially spine-injured patients, prehospital guidelines and protocols continue to show substantial variation. As standards evolve, input from frontline providers that reflects the practical realities of care in local circumstances should help shape future guidelines.

DECLARATIONS

Ethics approval and consent to participate

This study was performed in accordance with the Declaration of Helsinki and all relevant guidelines and regulations. It was approved by the University of Manitoba Health Research Ethics Board, HS22960 (H2019:252). Information about the aims and conduct of the study was provided and informed consent was obtained from all subjects before proceeding with the survey.

Consent for publication

N/A

Availability of data and materials

Portions of raw data are available in appendices. Remaining data are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Database quality assessment in research in paramedicine: a scoping review protocol

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ABSTRACT

Introduction The paramedic practice environment presents unique challenges to data documentation and access, as well as linkage to other parts of the healthcare system. Variable or unknown data quality can influence the validity of research in paramedicine. A number of database quality assessment (DQA) frameworks have been developed and used to evaluate data quality in other areas of healthcare. The extent these or other DQA practices have been applied to paramedic research is not known. Accordingly, this scoping review aims to describe the range, extent, and nature of DQA practices within research in paramedicine.

Methods and analysis This scoping review will follow established methods for the conduct (JBI; Arksey and O'Malley) and reporting (PRIMSA-ScR) of scoping reviews. In consultation with a professional librarian, a search strategy was developed representing the applicable population, concept, and context. This strategy will be applied to MEDLINE (National Library of Medicine), EMBASE (Elsevier), Scopus (Elsevier), and CINAHL (EBSCO) to identify studies published from 2011 through 2021 that assess paramedic data quality as a stated goal. Studies will be included if they report quantitative results of DQA using data that relate primarily to the paramedic practice environment. Protocols, commentaries, case studies, interviews, simulations, and experimental data-processing techniques will be excluded. No restrictions will be placed on language. Study selection will be performed by two reviewers, with a third available to resolve conflicts. Data will be extracted from included studies using a data-charting form piloted and iteratively revised based upon studies known to be relevant. Results will be summarized in a chart of study characteristics, DQA-specific outcomes, and key findings.

Ethics and dissemination Ethical approval is not required. Results will be submitted to relevant conferences and peer-reviewed journals.

Registration This protocol has been registered with the Open Science Framework. (Registration DOI: 10.17605/OSF.IO/Z287T)

ARTICLE SUMMARY

Strengths and Limitations

This study will examine the range, extent, and nature of database quality assessment practices in research in paramedicine.

The search strategy will capture a wide selection of potentially eligible studies, ensuring that the landscape of paramedic database quality assessment is comprehensively described and unique considerations of the paramedic practice environment not overlooked.

A piloted data-charting form will structure extracted data according to identified parameters that allow comparisons among included studies and with database quality assessment frameworks from other areas.

Database quality assessment practices in use might not be fully represented in published literature, biasing the results.

INTRODUCTION

Paramedicine is a growing and evolving discipline that has been variously described as emergency medical services (EMS), prehospital care, or emergency response.[*] As paramedicine enters its fifth decade as a distinct area of practice, numerous studies have cited the need for more research capacity to support the unique subject matter.[1-4] Although researchers are more frequently designing and conducting studies specifically about paramedicine in the paramedic practice environment,[5] research in the field faces challenges in accessing high-quality administrative data, particularly those that can link to patient outcomes in related databases.[1,2,6] This remains an ongoing issue at three basic levels.

First, data collection in paramedicine poses several unique challenges. These challenges begin with the nature of the work: often fast-paced and time-critical, paramedic care places simultaneous physical and cognitive demands on each provider's attention and time.[7-9] Additionally, the care environment can be unpredictable and disorganized, if not chaotic or unsafe, with frequent distractions and time pressures on scene.[7-10] The main source of patient information – the patient – is also sometimes unconscious or uncommunicative for various reasons, all of which delay real-time documentation, with attendant potential loss of data or accuracy.[9,11] Data input relies on individual care providers, not trained recorders in a dedicated role, which may result in questionable inter- and even intra-rater reliability.[9,11]

Second, not all data related to paramedic care are easily accessible. The vast majority of paramedic data are contained in the record of patient contact, known most often as the patient care report. Traditionally paper-based, the patient care report began transitioning to electronic

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[*] Terms in common use to describe paramedicine inadequately characterize the range of care currently practiced internationally. We have chosen to use "paramedicine" as a general term that includes traditional notions of "emergency" and "prehospital care", while accepting that emerging practice models frequently address non-urgent complaints in the community, avoid transport to hospital, and integrate with other allied health professions. We acknowledge international variety in the meaning of "paramedic", and use it to include emergency medical technicians, responders, and similar roles.

platforms in urban areas with established systems in the mid 2000s and early 2010s.[12,13] The process of adoption has been described as variable, non-linear, and characterized by ongoing upgrades, revisions, or changes instead of a single event.[12] It is not uncommon for adjacent geographical areas to be served by providers with mixed reporting platforms. It has also faced challenges in terms of funding and maintaining technical expertise.[13] Evaluations have noted the potential benefits of collecting large amounts of standardized data in electronic form, but that these have been inconsistently realized at the level of individual services.[12,13]

Third, where they do exist, electronic records have inherent limitations that apply to research in paramedicine. Healthcare in general has recognized the potential of electronic health records to support a wide variety of research, quality-improvement, public-health, and administrative purposes.[14-16] At the same time, there is also widespread acknowledgement of the limitations and pitfalls of conducting research with data collected for clinical use.[14,15,17-19] These limitations fall into several categories, including: the gap between the reason for data collection and its research use; variations in clinical practice, documentation standards, and data entry; and inconsistent use of electronic records within and among jurisdictions.[14,15,18,19] As an additional challenge, records of paramedic care are typically based on the event that occurred, not individual patients. Connecting paramedic care to patient outcomes therefore requires linkage based on data collected during the clinical encounter, and linkage success has been shown to vary widely and be subject to potential bias.[20] Acknowledging both the potential benefits and limitations of research based on electronic data, studies argue for clear and consistent ways of describing, evaluating, and sharing information about the data quality of electronic health records.[15]

Data quality practices are no less important in paramedic research than in general electronic health records, particularly considering the unique difficulties of data collection and the relatively recent integration of electronic record keeping. The continuing growth of paramedic research will depend on measures to improve, standardize, and communicate confidence in the source material. In some areas of paramedic practice, this process has begun with standards for and position statements on data capture and reporting.[21,22] Related healthcare fields, however, have developed numerous database quality assessment (DQA) frameworks that provide a conceptual structure as well as a technical map to assessing the quality of databases as a whole and the suitability of particular data for any specific use. No comparable DQA frameworks have been developed to address the unique circumstances of paramedic care, and the applicability of existing ones to the paramedic practice environment remains to be determined.

An overview of database quality assessment frameworks

In the most general terms, data quality is defined as "the extent that the data fulfill users' expectations and suit its intended purposes," or more simply, fitness for use.[11(p.20)] DQA frameworks commonly use a series of thematic domains to subdivide various components of data quality. Several reviews have noted that different frameworks use similar terminology, but frequently with slightly different meanings that reflect a particular setting or purpose. As an extreme example of the variety of terminology within the field, a review of DQA practices in public-health information databases counted 49 different terms used to describe various DQA attributes (analogous to domains) among the studies.[23] Within these, completeness, accuracy, and timeliness were evaluated most often, with the number of attributes assessed ranging from one to eight in any individual paper.

Individual studies showcase the variety of domains and assessment methods specifically related to a wide range of healthcare settings. These settings include a provincial-level administrative repository,[24] emergency nursing,[25] a framework synthesis of national-level clinical research networks,[26] and a model proposed for the Canadian primary-care environment.[16] Potentially relevant to paramedic research, a recent review summarized DQA practices in emergency medicine.[11] These authors proposed five domains applicable to the field (accuracy, completeness, timeliness, accessibility, and consistency), but did not address how the small number of included prehospital studies differed from or resembled their in-hospital counterparts.[11] Rather than targeting a specific healthcare setting, the Canadian Institute of Health Information (CIHI), a national-level data repository, uses a DQA framework that can be applied to a broad range of healthcare systems. It includes the following domains: relevance, accuracy and reliability, comparability and coherence, timeliness and punctuality, and accessibility and clarity.[27] Both comprehensive and general, this framework appears most adaptable to a range of settings and purposes.

Scoping Review Rationale

With paramedic research emerging as a distinct field with its own unique characteristics of data collection, future research will require common standards of methodological rigor. In the absence of a paramedic-specific DQA framework, DQA practices in paramedic research remain sporadically reported. Without area-specific guidance and in the context of a literature base that has not been described, a scoping review is an appropriate method to begin to define the boundaries of this topic. Metaphors of mapping are commonly applied to scoping review purpose, and multiple authors employ specific terminology to describe the dimensions of a research landscape, including range, extent, and nature.[28,29] Accordingly, this scoping review aims to assess the range, extent, and nature of DQA practices in paramedic research. Findings from this review will be used to assess whether a unique paramedic DQA framework might be needed or possible, and whether it could be developed using a "best fit" approach to combining a systematic review and qualitative evidence synthesis as described elsewhere.[30,31]

METHODS AND ANALYSIS

This protocol has been informed by guidance from the Johanna Briggs Institute (JBI) and is presented according to the stages proposed by Arksey and O'Malley.[32,33] It has been registered with the Open Science Framework (Registration DOI: 10.17605/OSF.IO/Z287T). The review will follow the guidelines of the scoping extension to the Preferred Reporting Items in Systematic Reviews and Meta-Analyses, PRISMA-ScR.[34]

Stage 1: Identifying the research question

Using the framework proposed by the JBI guidance on scoping reviews, parameters of this review are defined by the Population, Context, and Concept of related research.[32] Here, population identifies paramedic studies related to DQA (including quality improvement). This corresponds with elements of range, which will characterize the paramedic studies based on the location, date of publication, and clinical area of paramedic data being assessed. The context situates paramedic DQA studies within their setting and defines the extent of their assessment. Specifically, extent describes the level and breadth of data, where level distinguishes between, for example, data collected at the level of an individual service as compared to a country, and breadth reports the number of institutions included or connected at each level. The concept is defined as data quality, and includes DQA, information quality, or data accuracy, as distinct from clinical performance or measures of quality of care. The concept is further defined by specific characteristics that describe the nature of the assessment, such as the data fields assessed, methods of assessment, DQA framework (if specified), and applicable assessment domain.

Stage 2: Identifying relevant studies

A search will be undertaken to identify research studies that explicitly assess paramedic data quality as a stated goal. Studies will be limited to those that report quantitative results of DQA using data that relate primarily to paramedic practice environment. These criteria exclude protocols, commentaries, case studies, interviews, simulations, and experimental data-processing techniques. They also exclude studies that are not primarily focused on paramedic data or ones that evaluate databases that only incidentally include paramedic information. The paramedic practice environment will be interpreted broadly (encompassing urban, rural, remote, and military contexts), but will exclude special circumstances outside of regular practice, such as disaster and mass-casualty situations. No restrictions will be placed on language. If abstracts or articles in languages other than English are identified as potential candidates, arrangements for translation will be attempted on a case-by-case basis.

In consultation with a professional librarian, a provisional search strategy was developed using keywords and subject headings identified in available articles that represent the population, concept, and context. It has been iteratively revised with input from pilot assessments of draft versions. Aiming to include a wide selection of possibly relevant research, we initially applied no date filters. Next, we compared searches limited to the most recent 5, 10, and 15 years to balance numbers of citations with comprehensiveness. We choose approximately the last 10 years (rounded to include all of 2011) as a reasonable compromise between including all possibly relevant articles and those that are most recent and likely most applicable, while ensuring a sample of at least 10,000 citations (not counting duplicates). Therefore, studies will be limited to those from 2011 onwards. This search will be applied to the following databases: MEDLINE (National Library of Medicine), EMBASE (Elsevier), Scopus (Elsevier), and CINAHL (EBSCO). The search strategy, as applied to these databases, is included as Appendix 3.1, “Search strategy”. Search results will be imported into a data-management software platform, Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org).

Stage 3: Study selection

After removal of duplicates, title and abstract screening will be performed on a small sample of records (approximately 2.5%) to ensure a consistent application of the inclusion criteria. All remaining titles and abstracts will be screened by two reviewers independently. Any record selected by either reviewer will be included for full-text screening. Next, full text screening will be performed by two reviewers, with any differences resolved by discussion, with a third reviewer available if necessary.

Stage 4: Extracting data

Two reviewers will assess each paper selected for inclusion independently using a custom-designed data-charting form piloted on key articles. This form was developed by the reviewers using consensus on a sample of key articles known among the team and believed to be relevant to the study prior to the search (included as Appendix 3.2, “Data-extraction form”). This form includes 12 fields grouped by the three parameters (Range/Population, Extent/Context, Nature/Concept). Fields under the heading of Range include geographic location, year of publication, study purpose, and clinical area (if applicable). The level, breadth, and duration of data being assessed will be documented under the heading of Extent. Fields that make up the Nature parameter include the specific paramedic data assessed, the methods of assessment, summarized results of assessment, and domain of data quality being assessed, both as identified by the study and under the framework proposed by the CIHI (if possible).[27] Categorization under a framework has been included to provide information in cases where a domain was not identified, and to provide a consistent reference point for comparing all included studies. In the absence of any framework directly applicable to paramedic research, it is possible that no existing domains will apply to some identified DQA practices. To minimize this potential bias, the CIHI framework was chosen as being accessible, comprehensive, and broadly applicable to a range of topics.

Data-charting meetings will be held at regular intervals to compare results and assess the adequacy of the extraction form. If necessary, modification will be made, and additional data included (or removed). This process will occur iteratively until all records have been assessed by all reviewers with the ability to capture all relevant data.[32] Any modifications to the form will be recorded as changes to protocol and reported in the final results. Results from each reviewer using the final form will be compared and reconciled through discussion of all included studies. In accordance with methodological guidance for scoping reviews, critical appraisal will not be conducted on included studies.[34]

Stage 5: Collating, summarizing and reporting the results

Results of the search and screening process will be presented in text and using the PRISMA-ScR flow diagram.[34] Included studies will be summarized in a chart of characteristics for which data were charted (PRISMA-ScR item 18), and results will be synthesized in table or narrative format, depending on findings.[34]

Patient and public involvement

None.

Ethics and dissemination

As a review of publicly available studies, this study does not require ethical approval. The results will be submitted for publication to a peer-reviewed journal and presented to conferences and research gatherings.

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COMPETING INTERESTS

The authors declare none.

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Database quality assessment in research in paramedicine: a scoping review

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ABSTRACT

Background Research in paramedicine faces challenges in developing research capacity, including access to high-quality data. A variety of unique factors in the paramedic work environment influence data quality. In other field of healthcare, data quality assessment (DQA) frameworks provide common methods of quality assessment as well as standards of transparent reporting. No similar DQA frameworks exist for paramedicine, and practices related to data quality assessment are sporadically reported. This scoping review aims to describe the range, extent, and nature of DQA practices within research in paramedicine.

Methods This review followed a registered and published protocol. In consultation with a professional librarian, a search strategy was developed and applied to MEDLINE (National Library of Medicine), EMBASE (Elsevier), Scopus (Elsevier), and CINAHL (EBSCO) to identify studies published from 2011 through 2021 that assess paramedic data quality as a stated goal. Studies that reported quantitative results of DQA using data that relate primarily to the paramedic practice environment were included. Protocols, commentaries, and similar study types were excluded. Title/abstract screening was conducted by two reviewers; full-text screening was conducted by two, with a third participating to resolve disagreements. Data were extracted using a piloted data-charting form.

Results Searching yielded 10,105 unique articles. After title and abstract screening, 199 remained for full-text review; 97 were included in the analysis. Included studies varied widely in many characteristics. Majorities were conducted in the United States (51%), assessed data containing between 100 and 9,999 records (61%), or assessed one of three topic areas: data, trauma, or out-of-hospital cardiac arrest (61%). All data-quality domains assessed could be

grouped under 5 summary domains: completeness, linkage, accuracy, reliability, and representativeness.

Conclusions There are few common standards in terms of variables, domains, methods, or quality thresholds for DQA in paramedic research. Terminology used to describe other domains varied among included studies and frequently overlapped. The included studies showed no evidence of assessing some domains and emerging topics seen in other areas of healthcare. Research in paramedicine would benefit from a standardized framework for DQA that allows for local variation while establishing common methods, terminology, and reporting standards.

INTRODUCTION

Paramedicine[*] is increasingly recognized as a distinct healthcare profession with a unique body of knowledge.[1-3] Accompanying the growth of the profession, numerous studies and position papers have cited the need for expanded research capacity to develop quality benchmarks, investigate interventions, and evaluate outcomes within paramedic practice.[2,4-8] While researchers are more often conducting studies about paramedicine in the paramedic work environment, the field also faces barriers to growth.[6,9,10] Among these, access to high-quality data has been identified as a limiting factor relevant to almost all scenarios.[2,7,8,11]

The paramedic practice environment poses unique challenges to data collection.[5,10,12-14] Information about patient care is collected by practitioners for clinical purposes, not dedicated data-entry professionals for research use. Paramedic work is dynamic and complex, and takes place in uncontrolled and unpredictable environments, often subject to time and other pressures. Records of paramedic care, historically paper-based, are transitioning to electronic platforms, but face continuing challenges to implementation in many jurisdictions.[15,16] Paramedic services (as well as other emergency response agencies) typically organize documentation based on the incident, not the patient. Incident-based record keeping then requires linkage to subsequent files to assess outcomes for individual patients.[17] Data linkage using paramedic records varies in terms of success, not least in relation to the quality of initial data, and the linkage process can be susceptible to various forms of bias.[11,18]

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[*] Other common descriptions of paramedicine and paramedics reflect distinct aspects of the profession, whether in terms of the provider (emergency medical technicians, emergency responder, allied health provider) or the setting (prehospital care, out-of-hospital care, remote and retrieval medicine). No single description encompasses the international range of past and emerging practice models. Acknowledging this limitation, this review will use "paramedic" and "paramedicine" as generally inclusive of varied roles and settings.

Electronic health records in all contexts have benefits and limitations, but require consistent ways of describing, assessing, and integrating information about data quality.[19-21] These needs apply equally to paramedic data. Other healthcare professions have addressed these goals by developing conceptual tools for assessing data quality.[22,23] Usually termed data quality assessment (DQA) frameworks, these tools provide both templates for data evaluation and guidance for future data collection. They establish baseline methodological standards, which in turn support the methodological quality of future research and the validity of results. Existing DQA frameworks cover a wide range of settings and purposes. Typically, they are organized by domains – distinct aspects of data that together make up a total picture of data quality in any particular field. The number of domains included in any framework can vary widely, and the terms used to describe similar concepts frequently overlap. Although as many as 49 different domains have been described in one practice area, for example, frameworks typically include between one and eight domains, with key concepts such as completeness, accuracy, and timeliness appearing most frequently.[24] Frameworks also vary by area, and unique schemes have been developed or proposed for public health,[24] administrative data repositories,[25,26] emergency nursing,[27] emergency medicine,[14] digital health,[28] and primary care.[29] Although standards for and position statements on data capture and reporting have appeared in some areas of paramedicine,[30,31] no comprehensive framework dedicated to the paramedic work environment has been developed, and the adaptability of existing ones to the unique circumstances of paramedicine has not been determined.

As research in paramedicine continues to evolve, a common language and standard of data assessment will contribute to methodological rigor. In the absence of a paramedic-specific DQA framework, the landscape of data-quality practices remains uncharted. No prior reviews have collected information on this topic, and reporting of DQA practices within paramedicine remains sporadic. Currently, we lack a comprehensive view of what data is assessed, where and how it is assessed, and what the results of assessment might be. In a context where the subject matter is not well defined and current approaches not well described, a scoping review is an appropriate method to map the landscape of existing practice. To that end, this scoping review aims to describe the range, extent, and nature of DQA practices in research in paramedicine.

METHODS

A protocol of the methods has been previously registered with the Open Science Framework (https://doi.org/10.17605/OSF.IO/Z287T) and published.[32] Reporting follows the guidelines of the scoping extension to the Preferred Reporting Items in Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR).[33]

Search strategy

Under the guidance of a professional librarian and in accordance with established methods, a search was constructed to reflect the population, context, and concept of the research question, aiming to identify paramedic research studies that assessed data quality as a major goal.[34,35] Studies were included if they reported quantitative DQA results of data from the paramedic practice environment. This environment included urban, rural, remote, and military settings, but excluded special circumstances (disaster and mass-casualty situations). Studies were excluded if they were protocols, commentaries, case studies, interviews, simulations, or used experimental data-processing techniques. Studies that were not primarily concerned with paramedic data, or studies that evaluated databases that incidentally included paramedic information, were also excluded. No restrictions were placed on language. After iterative refinement of search terms and pilot testing of date ranges, the search was limited to 2011 – 2021 to balance comprehensiveness with recency. The search was applied to the following databases: MEDLINE (National Library of Medicine), Embase (Elsevier), Scopus (Elsevier) and CINAHL (EBSCO). The searches as applied are available in Appendix 3.1.

Study selection

Search results were imported into a data-management program (Covidence, Veritas Health Innovation, Melbourne, Australia). After duplicate citations were removed, all authors participated in title and abstract screening of 250 records to practice and discuss the application of inclusion criteria. All remaining records were independently screened by at least two reviewers, and any record selected by any reviewer was retained for full-text screening. Full-text records were assessed independently by two reviewers (NM, RP); differences were resolved with discussion, including the third reviewer (NL).

Data extraction

Data were extracted using a custom-designed data-extraction form (Appendix 3.2). This form included 12 fields grouped by the three parameters identified by the research question – the range, extent, and nature of DQA practices. Range was defined by geographic location, year of publication, study purpose, and topic (whether a clinical area, population, or specific circumstance). Extent was documented by the level, breadth, and duration of data being assessed. Specifically, level refers to the organizational area of the primary data and includes five categories: local (municipal or small area); regional (such as a regional health authority); sub-national jurisdiction (state/province/county); national; and international. Breadth contains two components: the number of services included and the number of linkages between paramedic data and other types of databases. The nature of the DQA was summarized by the specific variables or fields assessed, the methods of assessment, key results, and the domain of data quality being assessed, both as identified by the study and under the framework proposed by the Canadian Institute for Health Information (CIHI, if possible).[26] In accordance with guidance on scoping reviews, critical appraisal was not performed.[33]

Protocol amendments

These methods correspond to the registered study protocol with following exceptions. Based on the consensus of reviewers during data extraction, additional fields were added to the data-extraction form to better characterize the results. These include the number of records under consideration and any assessment threshold or measure of quality used in the study.

Reporting

Due to the number of extracted fields and the heterogeneity of the included studies, selected items have been reported within the parameters of extent and nature. Within extent, the number of records has replaced the duration of data being assessed. The presence of any assessment threshold or quality measure has been added to the nature parameter. Among other fields within nature, the results and methodology of the included studies have been illustrated with examples. Additionally, the variety of terms used to describe the domains of DQA among the included studies (up to 27) limited the usefulness of a purely descriptive approach in comparing findings. As a result, these domains have been grouped by similarity under the most applicable domain name. This grouping yielded a descriptive summary of the assessed data in five domains; as far as possible, domains as identified in the original articles were considered in the way they were presented and not re-interpreted. While the five summary domains are consistent with vocabulary used among existing DQA frameworks, common usage with both frameworks and individual included articles shows overlapping and sometimes contradictory meanings. For example, the term “granularity” was used as both a measure of completeness of a record (therefore included under the domain of completeness),[36,37] and to describe the precision of the data (included as part of reliability).[38] These results list domain names along with other terms used among the included studies, even when groups appear inconsistent, to reflect the heterogeneity of practice.

RESULTS

Database searching identified 10,105 unique articles (Figure 4.1). After title and abstract screening, 199 remained for full-text review. Of these, four were in languages other than English (one each of German, Spanish, Russian, and Persian [Farsi]); these were professionally translated for further assessment. Among all articles selected for full-text assessment, 102 were excluded for reasons cited. Additional duplicates (n=18) identified at this stage included abstracts for which full articles using the same data and substantially similar results were also present. Ninety-seven articles were included in the analysis.

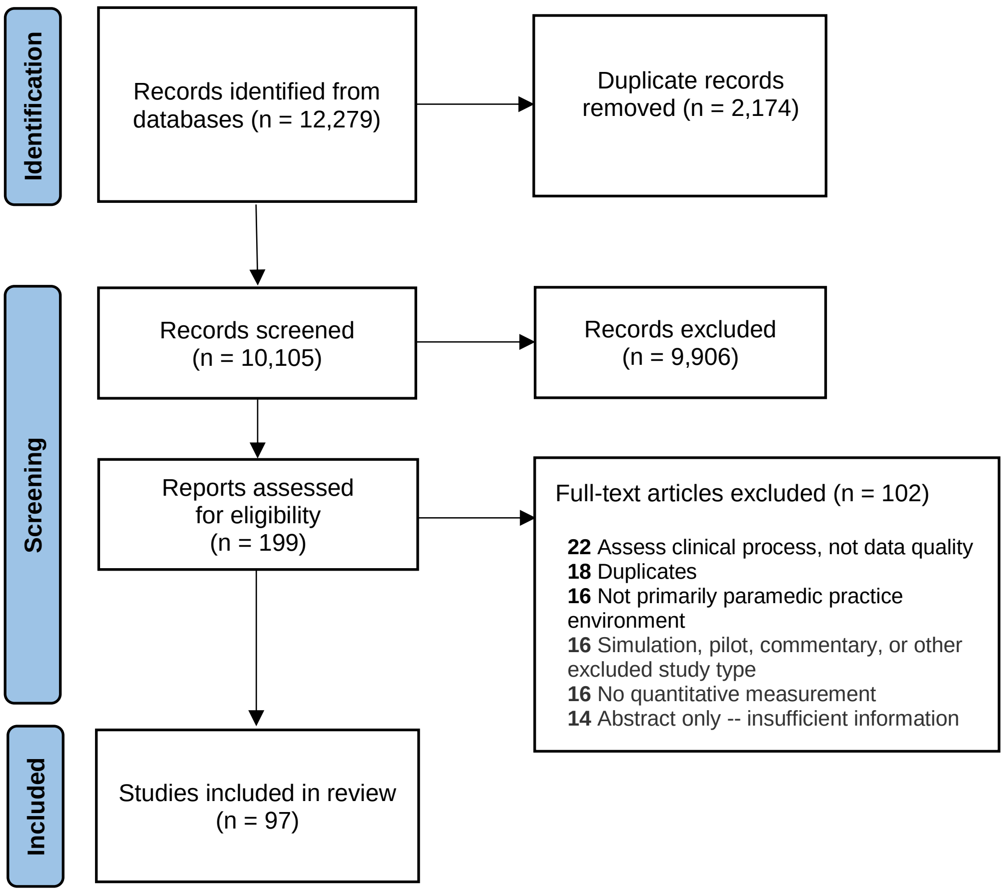

Figure 4.1 PRISMA-ScR flow diagram of study selection

Study characteristics

Table 4.1 lists the main characteristics of included studies, as well as selected extracted data. (Appendix 4.1 lists full citations of all included studies.)

Table 4.1: Characteristics of included studies

	RANGE			EXTENT				NATURE
Study	**Year**	**Location**	**Topic**	**Level of data****	**Number of services**	**Number of linkages**	**Number of records (10^x)*****	**Domains assessed (as summarized)**
Abir et al.	2021	USA	Data	Sub-national	More than 10	None	6	Completeness
Alstrup et al.	2019	Denmark	Data	National	Single	None	4	Completeness, Accuracy
Andrews et al.	2019	Australia	Trauma (MVCs)	Sub-national	2 to 9	None	3	Completeness, Reliability
Andrusiek et al.*	2012	Canada	Police use of force	Local	Single	None	2	Linkage
Asimos et al.	2014	USA	Stroke	Sub-national	More than 10	None	3	Completeness
Babcock et al.*	2019	USA	Sepsis, Pediatrics	Regional	More than 10	One	3	Completeness
Barley et al.*	2021	UK	Vitals / History	Regional	Single	None	5	Completeness
Berben et al.	2015	Holland	Pain	Regional	More than 10	None	3	Completeness
Bergrath et al.	2011	Germany	Data	Local	Single	None	3	Completeness
Bessant et al.*	2017	UK	Trauma (tourniquets)	National	2 to 9	None	1	Completeness
Betlehem et al.*	2013	Hungary	Stroke	Sub-national	Single	One	2	Completeness
Blanchard et al.	2021	Canada	Data	Regional	Single	One	3	Linkage, Representativeness
Bloomer et al.	2013	Australia	Airway (intubation)	Local	Single	None	2	Completeness
Bradley et al.	2017	Canada	Trauma	Sub-national	Single	None	2	Completeness
Carroll et al.	2015	Australia	Data	Sub-national	Single	Multiple	6	Linkage
Chikani et al.	2020	USA	Data	Sub-national	More than 10	One	5	Linkage
Clark et al.	2019	UK	Data	Regional	Single	One	5	Linkage
Coventry et al.	2014	Australia	Other cardiac	Local	Single	One	2	Completeness, Accuracy, Reliability
Cox et al.	2013	Australia	Data	Sub-national	Single	None	3	Linkage
Crilly et al.	2011	Australia	Data	Sub-national	Single	One	4	Linkage
Cunningham et al.	2014	Australia	Trauma (falls)	Regional	Single	One	2	Completeness
Deasy et al.	2013	Australia	OHCA, Pediatrics	Sub-national	Single	One	2	Linkage
Demel et al.*	2018	USA	Stroke	Sub-national	More than 10	One	4	Completeness
Depinet et al.	2019	USA	Sepsis, Pediatrics	Regional	More than 10	One	2	Completeness, Reliability
Dewolf et al.	2021	Belgium	OHCA	Local	Single	One	2	Accuracy

* Denotes abstract
** Sub-national refers to state/province/county, as per article.
*** The number of records is expressed as an order of magnitude. For example, "3" represents 10^3, meaning between 1,000 and 9,999 records
ACS, acute coronary syndrome; MVC, motor vehicle crash; MI, myocardial infarction; N/A, not applicable; OHCA, out-of-hospital cardiac arrest; STEMI, ST-elevation myocardial infarction; TBI, traumatic brain injury; UK, United Kingdom; USA, United States of America

Engels et al.	2021	Canada	Trauma	Regional	2 to 9	Multiple	4	Linkage
Fein et al.	2014	Australia	Trauma (burns), Pediatrics	Regional	Single	None	2	Completeness
Fix et al.	2021	USA	Substance use	Sub-national	More than 10	One	4	Linkage
Fosbol et al.	2013	USA	Other cardiac	Sub-national	More than 10	One	3	Linkage, Reliability, Completeness
Foster et al.	2017	USA	OHCA	Local	Single	One	3	Completeness, Accuracy
Frisch et al.	2014	USA	OCHA	Local	2 to 9	None	2	Accuracy, Reliability
Gaeeni et al.	2021	Iran	Data	Sub-national	Single	None	2	Completeness
GarciaMinguito et al.	2012	Spain	Trauma (domestic violence)	Local	2 to 9	None	2	Completeness
Gerhardt et al.	2016	USA	Pain	Regional	Single	One	3	Completeness
Govindarajan et al.*	2011	USA	Data	Regional	2 to 9	Multiple	3	Linkage
Gravens et al.*	2018	USA	OHCA, Vitals / History	Local	Single	One	2	Completeness
Halbesma et al.*	2019	UK	OHCA	National	Single	Multiple	4	Linkage
Hern et al.*	2012	USA	Pain	Local	Single	None	4	Completeness
Hu et al.	2014	USA	Trauma, Vitals / History	Sub-national	Single	None	2	Reliability, Completeness
Hughes-Gooding et al.	2020	UK	Seizures	Regional	Single	Multiple	5	Linkage
Ibrahim et al.*	2019	USA	Stroke	Sub-national	More than 10	One	3	Linkage
Jaureguibeitia et al.	2021	USA	OHCA	National	More than 10	None	3	Representativeness, Accuracy
Ji et al.	2018	UK	OHCA	Regional	2 to 9	Multiple	3	Linkage
Katzer et al.	2012	USA	Data	Local	Single	None	2	Completeness
Kearney et al.	2016	Rwanda	Trauma	Local	Single	One	3	Linkage
Ko et al.*	2012	Unknown	OHCA	Local	Single	One	3	Completeness
Kummer et al.	2017	USA	Stroke	Local	Single	None	1	Completeness
Lerner et al.	2014	USA	Pediatrics	National	More than 10	None	5	Completeness
Lerner et al.	2021	USA	Pediatrics	National	More than 10	None	5	Representativeness
Li et al.*	2016	Unknown	Vitals / History, Geriatrics	Local	Single	One	2	Completeness
Lippert et al.*	2019	Denmark	OHCA	National	2 to 9	One	3	Completeness
MacDougall et al.	2019	Canada	Substance use	Sub-national	Single	Multiple	3	Linkage
Mann et al.	2015	USA	Data	National	More than 10	None	3	Completeness, Representativeness
McDonald et al.*	2020	USA	OHCA	Local	Single	One	1	Linkage
Miller et al.	2021	USA	Data	National	More than 10	None	6	Representativeness
Mumma et al.	2015	USA	OHCA	Sub-national	More than 10	Multiple	4	Linkage

* Denotes abstract
** Sub-national refers to state/province/county, as per article.
*** The number of records is expressed as an order of magnitude. For example, "3" represents 10^3, meaning between 1,000 and 9,999 records
ACS, acute coronary syndrome; MVC, motor vehicle crash; MI, myocardial infarction; N/A, not applicable; OHCA, out-of-hospital cardiac arrest; STEMI, ST-elevation myocardial infarction; TBI, traumatic brain injury; UK, United Kingdom; USA, United States of America

Mysliwiec et al.*	2015	USA	Geriatrics	Local	Single	None	2	Completeness
Newgard et al.	2011	USA	Data	Sub-national	More than 10	One	4	Completeness, Linkage
Newgard et al.	2012	USA	Data, Trauma	Regional	More than 10	Multiple	4	Completeness, Linkage
Newgard et al.	2012	USA	Data, Trauma	Regional	More than 10	Multiple	4	Accuracy, Reliability
Newgard et al.	2018	USA	Data, Trauma, Geriatrics	Regional	More than 10	Multiple	4	Completeness, Accuracy, Linkage
Nishiyama et al.	2014	Unknown	OHCA	International	More than 10	None	5	Completeness
Oostema et al.	2020	USA	Stroke	Sub-national	More than 10	One	3	Linkage, Representativeness
Oud et al.	2019	Australia	Airway (intubation)	Local	Single	None	1	Completeness
Outterson et al.*	2016	Unknown	Other cardiac, Vitals/History	Local	Single	One	2	Reliability
Perez et al.*	2017	USA	Trauma (TBI)	Regional	2 to 9	One	2	Accuracy
Perez et al.*	2017	USA	Trauma (TBI)	Regional	2 to 9	One	2	Accuracy
Poulsen et al.	2020	Denmark	Vitals / History	Regional	Single	None	5	Completeness, Accuracy
Rajagopal et al.	2017	UK	OHCA	National	2 to 9	Multiple	4	Linkage
Randell et al.*	2020	USA	Data	Local	Single	None	2	Completeness
Redfield et al.	2020	USA	Data	Local	Single	One	4	Linkage
Reisner et al.	2012	Unknown	Trauma, Vitals / History	Local	Single	One	2	Reliability
Richards et al.*	2018	USA	Stroke	Local	Single	One	2	Linkage
Robinson et al.	2016	USA	Trauma	Regional	Single	One	2	Completeness
Rykulski et al.*	2021	USA	OHCA	Sub-national	More than 10	One	3	Completeness
Savary et al.*	2020	France	OHCA	Regional	2 to 9	One	2	Completeness
Saviluoto et al.	2020	Finland	Data	International	Single	None	5	Completeness
Schauer et al.	2017	USA	Trauma - all	Regional	Single	One	2	Completeness
Scott et al.	2013	USA	Trauma	Sub-national	More than 10	One	2	Linkage
Seymour et al.	2014	USA	Data	Regional	More than 10	Multiple	3	Linkage, Representativeness Completeness
Silvestri et al.*	2012	USA	Airway (intubation)	Local	Single	None	2	Accuracy
Staff et al.	2011	Norway	Trauma (MVCs)	Sub-national	More than 10	None	2	Completeness, Reliability, Representativeness
Stephanian et al.*	2020	Canada	Mental Health, Trauma (falls)	Local	Single	Multiple	3	Linkage, Representativeness
Stromsoe et al.	2013	Sweden	OHCA	Sub-national	2 to 9	None	3	Completeness, Representativeness
Sundermann et al.	2015	USA	OHCA	Local	Single	None	3	Completeness, Accuracy
Swor et al.	2018	USA	OHCA	Sub-national	More than 10	One	4	Linkage
Tonsager et al.	2019	Multinational	Data	International	2 to 9	None	3	Completeness

* Denotes abstract
** Sub-national refers to state/province/county, as per article.
*** The number of records is expressed as an order of magnitude. For example, "3" represents 10^3, meaning between 1,000 and 9,999 records
ACS, acute coronary syndrome; MVC, motor vehicle crash; MI, myocardial infarction; N/A, not applicable; OHCA, out-of-hospital cardiac arrest; STEMI, ST-elevation myocardial infarction; TBI, traumatic brain injury; UK, United Kingdom; USA, United States of America

Tonsager et al.	2020	Multinational	Vitals / History	International	More than 10	None	4	Accuracy, Completeness, Representativeness
Tainter et al.	2020	USA	Trauma (MVCs)	Sub-national	More than 10	One	4	Linkage
Therien et al.	2011	USA	Trauma (combat)	Regional	Single	One	4	Completeness
Timoteo et al.	2020	Brazil	Data	Local	Single	None	2	Completeness
Tlimat et al.*	2016	USA	Data	Local	Single	One	4	Linkage
Tsur et al.	2020	Israel	Trauma (combat)	National	Single	One	4	Completeness
Wilharm et al.	2019	Germany	Airway (capnometry)	International	More than 10	One	4	Completeness
Winter et al.*	2017	UK	Pain	Regional	Single	None	2	Completeness

* Denotes abstract

** Sub-national refers to state/province/county, as per article.

*** The number of records is expressed as an order of magnitude. For example, "3" represents 10^3, meaning between 1,000 and 9,999 records

ACS, acute coronary syndrome; MVC, motor vehicle crash; MI, myocardial infarction; N/A, not applicable; OHCA, out-of-hospital cardiac arrest; STEMI, ST-elevation myocardial infarction; TBI, traumatic brain injury; UK, United Kingdom; USA, United States of America

Range of included articles

Among the 97 included articles, 39 (40%) were published from 2019 to 2021, with the remainder spread relatively evening across the preceding years. Forty-nine studies (51%) were conducted in the United States (US); Australia (n=10), the United Kingdom (n=8), and Canada (n=6) were the next most frequent locations. Figure 4.2 lists all countries, as well as the breakdown of US States, where applicable. Abstracts (as well as one letter) accounted for 27 (28%) included items; the remainder (70, 72%) were full articles. Included items studied diverse topics spanning clinical areas, populations, and specific situations. Studies were coded to allow for multiple subject areas; Figure 4.3 illustrates the number of studies per topic out of all mentioned (n=111). Topics related to data linkage or the data management without reference to a clinical area (labelled, “Data”) were the most frequent area of study (n=27, 24%). The next most common topic was trauma (n=21, 19%), followed by out-of-hospital cardiac arrest (OHCA) (n=20, 18%). These three areas made up the majority (68/111, 61%) of all areas studied.

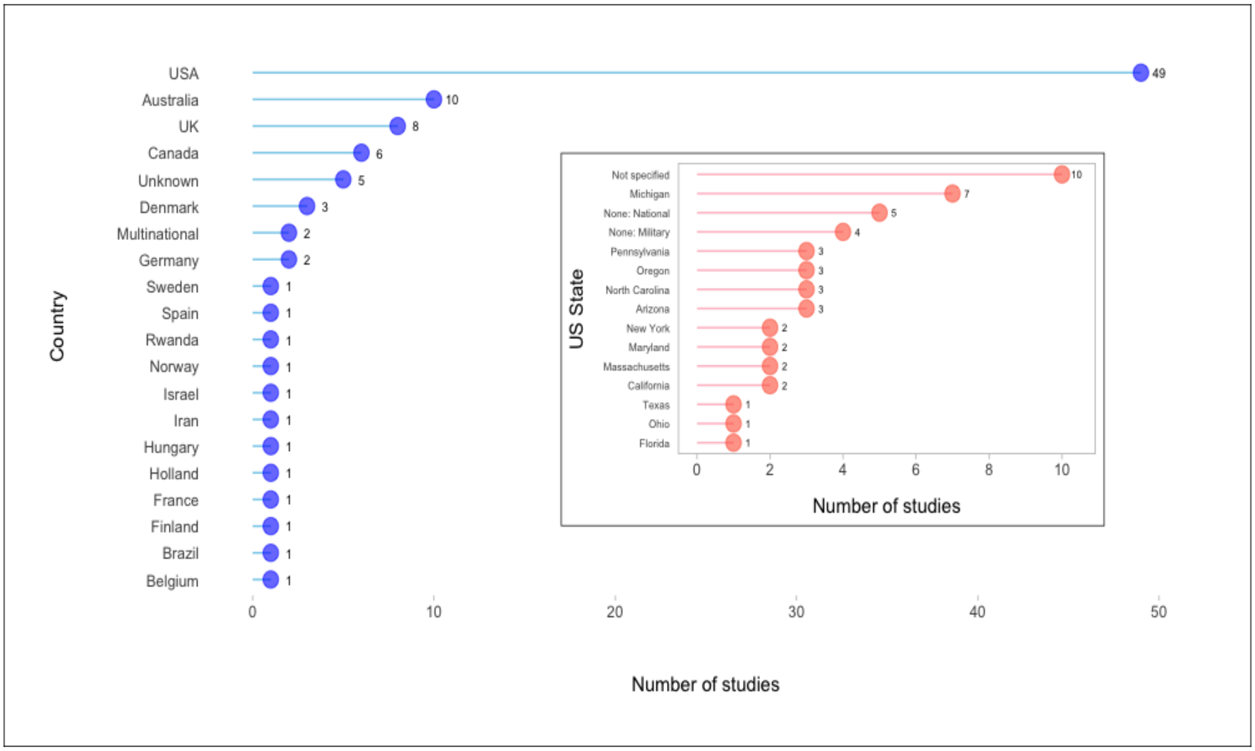

Figure 4.2: Geographic location of data quality assessment studies in research in paramedicine (n = 97), listing the number of studies by country (main panel), and by State (or national / military) among studies from the United States (inset).

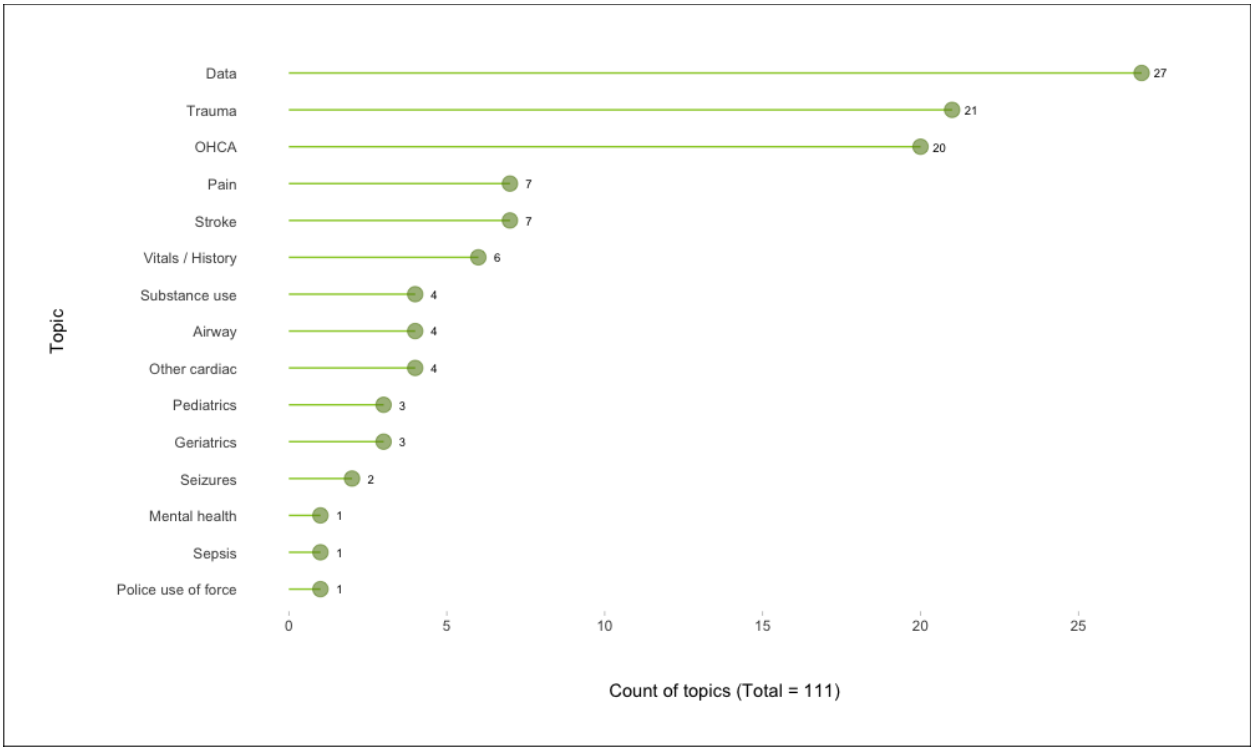

Figure 4.3: Topic (clinical area / population / situation) of data quality assessment studies in research in paramedicine, listing the number of areas (total = 111) among all studies (n = 97).

Extent of included studies

Figure 4.4 displays the extent of included studies according to the identified sub-categories. The level at which studies assessed data was spread relatively evenly among local (n=28, 29%), regional (n=25, 26%), and state/province/county (n=28, 29%) (Figure 4.4A). The majority of studies (n=51, 53%) assessed data belonging to one paramedic or prehospital agency (Figure 4.4B). In terms of linkage, 39 (40%) studies did not link paramedic or prehospital data to any other sources, whereas forty-four (45%) linked to a single type of database (whether hospital, emergency department, or other related source), and 14 (14%) linked to multiple databases of different kinds (Figure 4.4C). The majority of studies reviewed between 100 and 9,999 records (n=59, 61%), with only 6 (6%) reviewing fewer than 100 and 4 (4%) reviewing more than 1 million (Figure 4.4D). Considering combinations of the level of data assessed (Figure 4.4BA), the number of services (Figure 4.4B), and number of linkages (Figure 4.4C), the three largest exclusive groups of characteristics involved: a local, single service linked to a single type of database (13/97); state-level data, represented by 10 or more services, linked to a single type of database (13/97); and a local, single service with no linkage (12/97).

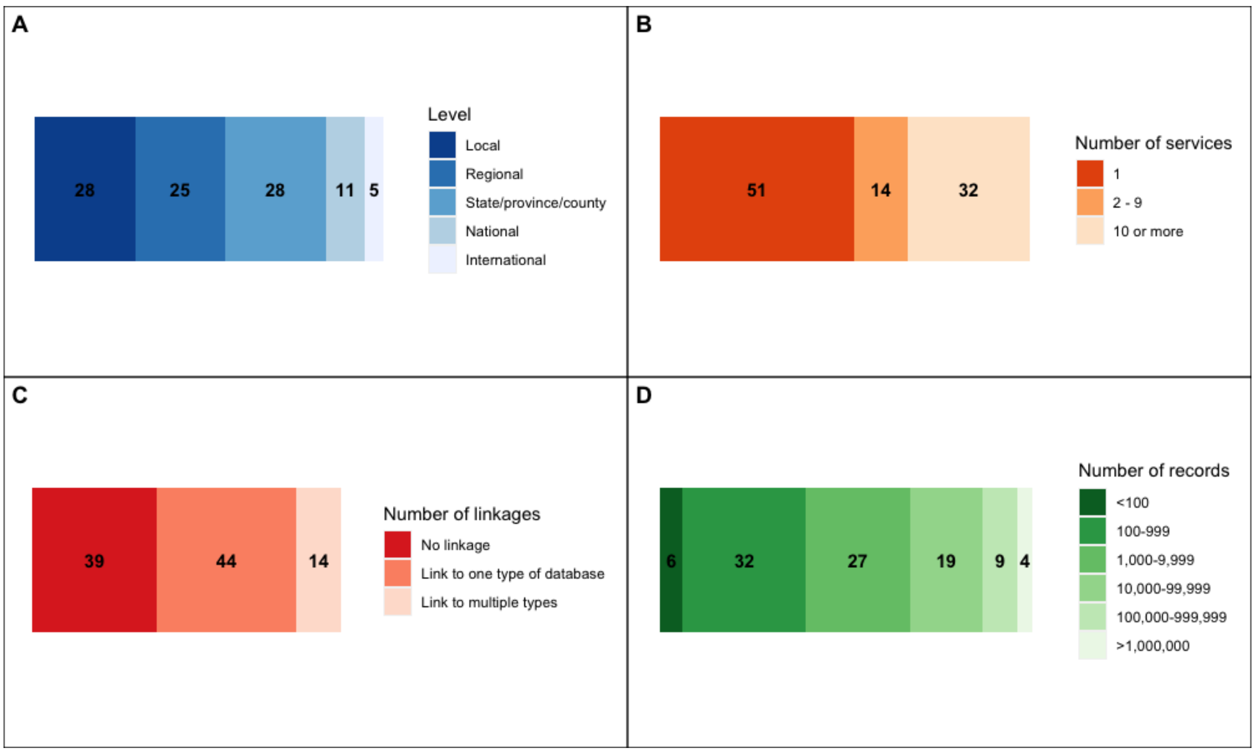

Figure 4.4: Extent of data quality assessment studies in research in paramedicine, measured by (A) the level of data assessed, (B) the number of services included, (C) the number of types of linkages to other databases, and (D), the number of records assessed. Each chart includes all studies (n = 97).

Nature of included studies

Table 4.2 summarizes the domain names and explanations derived from how the studies described their assessment. It also includes any quality measures applied by included studies, grouped by domain. As listed in Table 4.1, some studies assessed multiple areas, yielding 126 instances of an assessed domain.

Categorization of the study domains according to the CIHI framework yielded only two main categories (accuracy and reliability and comparability and coherence). As incidental findings, one study adapted a DQA framework from public-health surveillance and applied some domains to its prehospital data.[39] Similarly, two studies applied a reporting guideline specific to the methodology of database linkage.[40,41] No other DQA reporting guidelines were noted.

The DQA domains of the included studies are summarized below, with examples of representative and unique studies.

Table 4.2: Summary of data quality assessment domains in studies on research in paramedicine

Domain	Count (percent)*	Other terms used	Description	How measured	Quality measure
Completeness	57 (45)	Missingness, adherence, availability, unknown/not reported, granularity	Measure of how often a variable is present when expected. Complement of missingness.	Proportion and percent	Raw percent complete, weighted percent complete, percent legible
Linkage	34 (27)	Match	Can records belonging to the same person or event be linked between different databases? How well? By what means?	Probabilities, percent success, sensitivities, specificity, positive predictive value, negative predictive value (and related measures: false positive, false negative)	Match-weight cut-off, match quality
Accuracy	14 (11)	Validity, correctness, concordance, plausibility, ascertainment, capture, incidence, population	Does the variable measure what it claims to measure? Is the result plausible or possible?	Proportion and percent, sensitivity, specificity, positive predictive value, negative predictive value	-
Reliability	10 (8)	Agreement, precision, consistency, variation, aggregation, uniqueness, granularity, quality	Is the measurement free from error and consistent over time and among observers?	Difference in proportions, kappa, intraclass correlation coefficient, correlation, others (Andrews, Reisner)	-
Representativeness	11 (9)	External validity, bias, generalizability, concordance	How well does the data correspond to other data expected to be similar? How well do parts of the data correspond when they are expected to be similar? Is the data biased in some way?	Difference in proportions, correlation, kappa, sensitivity	Proportions, absolute standardized difference, ±5% difference

* 126 domains assessed among 97 studies

Completeness

Completeness measures how often a variable is present when expected or required. It is usually expressed as a proportion or percent of all potential entries. Depending on the purpose of the study or the nature of the results, this is often expressed as its complement, missingness. This domain appeared most frequently, and was present in 57 studies, accounting for 45% of all domains documented (n=126).

Among included studies, completeness frequently measured the variables deemed most important to each study's purpose. As a representative example, Abir et. al. found only five of 18 key variables were present in over 90% of cases.[42] Other large studies provided similar ranges,[43] although some report wide discrepancies among individual services in aggregated data.[44,45] Certain categories, such as mechanism of injury, frequently showed relatively low values[38]; emergency department (ED) disposition, where reported, was negligibly complete in paramedic databases (cited in one study at less than 5%[46]). Additional contrasts in the completeness of basic variables can be seen between different settings, such as helicopter emergency medical services (EMS) agencies and the military, where completion rates were consistently high and low, respectively.[36,47-49]

Many studies assessed the completeness of variables unique to their study areas or populations. Examples include symptom presence or duration in stroke or ACS cases,[50-54] key vital signs such as temperature in sepsis,[55,56] social or medical history fields,[57-60] pain scores,[61-64] tourniquet use,[65] airway characteristics,[66,67] burns,[68] domestic violence,[69] capnometry in trauma,[70] and a range of variables in OHCA.[71-73]

Linkage

Thirty-four studies (representing 27% of all domains) assessed how well paramedic or prehospital data could be linked to other sources of information. Included studies detailed a range of techniques for linkage, broadly divided between deterministic and probabilistic approaches, occasionally supplemented by manual review for confirmation or optimization.[74,75] While most cases evaluated linkage of EMS to ED or hospital records, some studies linked datasets by starting with records identified in the ED (or end-database) and linking back to their EMS counterparts,[76,77] or working in both directions.[78,79]

Overall rates of linkage varied among the included studies. In one case, an optimized iterative deterministic approach yielded 97% success in linking records of EMS patients transported to an ED, with no false positives.[18] Other studies found similar results with a variety of optimization strategies.[41,80-82] In the case of large-scale datasets (greater than 1 million patients), one assessment also reported successful linkage of 97.2% of expected records, with a false positive rate of 0.4% using mixed deterministic and probabilistic approaches.[40] Studies with results at low end of the range included several linking trauma patients to hospital outcomes, ranging between 15-88%, and 49-60% specifically for ground transport.[83,84] Others examining OHCA (34%[85]) and stroke (26%[86]) marked the lowest reported rates within those clinical areas.

Within studies examining linkage between paramedic data and other sources, several looked at unique clinical areas or populations. These included a manual review of EMS charts to identify police use-of-force encounters,[87] as well as studies aiming to identify non-fatal agricultural injuries and instances of suicide by bridge-jumping.[77,88] In addition to these various applications, fundamental methodological details differed across studies. Some studies reported initially screening and excluding records with missing linkage data.[41,89,90] While those records would presumably have yielded false matches or unsuccessful linkages, excluding them outright would be expected to yield higher success rates than those reported by studies including all eligible cases.

Accuracy

Among a range of terms used to describe similar concepts, accuracy refers to the extent to which a variable records what it was designed to measure.[25] Accuracy is assessed against a reference thought to be valid or true, sometimes referred to as a gold standard. Among included studies, it was expressed in terms of proportions, percents, and diagnostic test statistics (sensitivity, specificity, positive predictive value, negative predictive value). Evaluations of accuracy were present in 14 studies, accounting for 11% of all domains assessed.

Several topics featured multiple studies assessing accuracy. For example, three studies of OHCA evaluated the accuracy of documented events and timepoints in the paramedic record in comparison to video or audio recordings or data from a defibrillator/monitor – in each case, a source thought to represent a gold standard.[73,91,92] All showed discrepancies between written and recorded data in terms of detection of return of spontaneous circulation and re-arrest,[73] the rate and depth of chest compressions,[92] and total CPR time and total adrenaline dose.[91]

Vital-sign documentation was another common topic area for accuracy evaluation. Two studies used continuous vital signs recorded by a monitor to evaluate documented blood pressure and oxygen-saturation values among patients with traumatic brain injuries.[93,94] Others assessed records for entries deemed implausible, finding few vital signs or response times outside of clinically plausible ranges.[43,95] Other studies compared the accuracy of paramedic or prehospital record to gold-standard documentation contained in hospital charts.[52,58]

Different approaches to assessing data accuracy aimed to establish the validity of individual variables or entire cohorts. Newgard et al. (2018) described evaluating a patient cohort derived using electronic methods against a group of manually reviewed records.[83] The validity of various data points in the electronic group ranged from a high of 97.4% sensitive and 99.8% specific for in-hospital mortality to a low of 18.2% sensitive and 88.0% specific for an abdominal-pelvic Abbreviated Injury Scale score of ≤ 3.[83] Similar studies investigated the validity of case ascertainment and multiple imputation of missing values after record linkage.[45,96]

Reliability

Reliability measures the extent to which measurements and documentation are consistent or how much variety would appear over repeated measures.[25] In contrast to measures of accuracy and validity, reliability assesses agreement between two values without assuming that one represents a reference standard. In place of statistics that measure proximity to a value, reliability is expressed in terms of correlation, kappa, intraclass correlation coefficient, difference, differences in proportions, and unique measures derived by individual studies.[38,97] Ten studies presented quantitative data falling under these headings, representing 8% of domains evaluated.

Whereas several studies evaluated the accuracy of prehospital documentation of patient medical history in comparison to hospital records, some analyses assessed the same information in terms of agreement. For example, Coventry et. al. found that paramedic and hospital documentation showed high agreement in recording the presence of chest pain among patients with myocardial infarctions (adjusted kappa, k=0.87).[52] A similar approach was used by studies assessing other clinical areas (such as sepsis[56]), as well as data-processing (comparing manual and electronic cohort development[96]). Other outcomes were assessed using correlation coefficients to compare, for example, paramedic and hospital documentation for the time between first medical contact and definitive treatment in the case of STEMI (r=0.87).[98]

When applied specifically to the spread or clustering of measurements, reliability is commonly termed precision. (This was also referred to as granularity in the case of time stamps.[38]) In assessing documented event times in OCHA in comparison to audio recordings, Frisch et al. found wide variability in reported times – imprecision that they argue should be accounted for in future analyses.[99] Precision has also been assessed in terms of how many different ways variables are recorded, both within and across datasets. Staff et al. examined whether vital signs in trauma calls were recorded as exact numbers, categories, or inferred from free-text.[100] Andrews et al. used the term uniqueness to quantify the similarity of categorical data within a given field. In one set of assessed records, they assigned a value of 27% to mechanism of injury, indicating low level of uniqueness among records that result from options constrained by a drop-down menu.[38] Common variables recorded differently both within and across datasets were cited in other instances, including vital signs,[101] chief-complaint coding among different services,[44], and even ostensibly standardized variables in OHCA reporting.[71]

Representativeness

Representativeness refers to the extent to which data corresponds to other or reference populations or to the degree to which data can be applied outside of the study group. Among included articles, representativeness was assessed most often by comparisons of proportions, although correlation, agreement, and unique statistics were also used.[76] Eleven studies included assessments of representativeness, accounting for 9% of domains.

Studies in paramedic research used a variety of approaches to defining a reference group. Mann et. al. assessed the generalizability of the 2012 National Emergency Medical Services Information System (NEMSIS, a national database of EMS information in the United States) by comparing patient ages as documented in NEMSIS to the ages of all ED arrivals documented in other sources (the results showed high correlation, r>0.9).[46] Lerner et al. (2021) evaluated a pediatric-specific database with the complete cohort of all pediatric records in NEMSIS and found meaningful differences in patient race and chief complaints between the two groups.[102]

Other linkage studies assessed their results for bias by examining differences between linked and unlinked cohorts. Within particular clinical areas, such as stroke and OHCA, indications of bias between matched and unmatched groups were seen within topic-related factors, such as age, event location, bystander CPR, or return of spontaneous circulation.[76,92,103,104] Another study linking paramedic and hospital records tracked the degree to which an optimized strategy for case matching mitigated bias found in a standard approach.[18]

Quality thresholds

Also included as an attribute of the nature of studies on research in paramedicine, the concept of quality thresholds appeared sporadically among the included studies. Despite these mentions, there are no established guides, thresholds, or systems for defining what constitutes quality data or determining what is high versus low quality. Many studies discussed the relevance of their results, finding them to be feasible or applicable (or not) in individual cases. Few studies reported applying any quality threshold; those that did are described below.

The domain of completeness offered clear and simple options for testing. In one study, completeness of less than 90% (or greater than 10% missingness) was judged to be low quality.[42]

Others used similar thresholds.[49,69,105,106] Within studies examining linkage of paramedic data with other sources, papers sometimes applied a pre-specified probability cut-off that determined a match or non-match, with those at or near the threshold value being selected for manual review. This was often listed as a probability at or straddling 0.9,[45,83,96] although 0.5 was also used,[74] as were levels that varied within the study according to patient block.[85] Other studies used ratings of match quality depending on the number or type of variables that established the link.[103,107,108]

Within the domain of representativeness, few studies worked with a standard beyond reporting different proportions among their study groups. In contrast, Lerner et al. (2021) described applying a threshold of plus or minus 5% as indicating a meaningful difference between their sample and reference populations.[102] Oostema et al. used an absolute standardized difference, defined as the average difference of each variable as a percent of its standard deviation, with values greater than 0.1 indicating a significant difference.[76]

DISCUSSION

The studies identified in this scoping review all present quantitative results of DQA practices in research in paramedicine. As a group, they make up a sample of DQA as recently applied in this area. Several features of the collection stand out among the individual variety. Although many countries are represented, they are not distributed evenly: slightly more than half of the studies took place in the United States. Similarly, in terms of topic or clinical area, the majority of included studies clustered around data management, trauma, and OHCA. The number of studies on DQA appears to be increasing over time. The proportion of abstracts without later publications (28%) appears to be relatively high, possibly indicating a subordinate role for DQA.

This study was not designed to assess the relative frequency of these traits as compared to paramedicine in general, and it remains to be determined whether these distributions reflect all research in paramedicine, or whether DQA practices are over- or under-represented in particular ways.

The purposes of included studies varied widely. In many cases, the DQA component appeared to be ad hoc, reflecting the unique methodological requirements of individual studies and often presented as an accompanying abstract or article to an investigation with some other purpose. Where evident, accumulated expertise appeared to have been developed over the course of multiple studies within related research groups, rather than across researchers within the profession.[44,45,83,96,102,109] The variety in purpose was also related to the extent of included studies. Many featured a single service examining its own data or linking to a single hospital or ED. In contrast, there were several examples of regional, state, or national-level data being integrated with multiple external databases with high levels of linkage success, either for specific research purposes or routine outcome evaluation.[18,40,83,103,110] These examples demonstrate progress in overcoming oft-noted barriers to data linkage and outcome evaluation.[2,11]

While the results of individual studies were too variable to draw specific conclusions about paramedic data quality, some generalizations about the nature of DQA practices emerged. Many authors emphasized the central priority of data completeness in paramedic research. A high or acceptable level of completeness was seen as essential for research within any individual database as well as for linkage, which is itself necessary for outcome evaluation. Abir et al. stated simply, “The most basic measure of dataset quality is completeness”.[42, p.2] Although relationships between domains were not routinely assessed, one study calculated an r^2 of 0.52 to quantify the association between data completeness and linkage success.[85] Apart from this consensus, there were few (if any) common standards in terms of variables, domains, methods, or quality thresholds for DQA in paramedic research. A DQA framework was mentioned by only one included study (which was only partially applicable to prehospital data).[39] Relatedly, although a reporting guideline exists for data-linkage methodology, it was referenced by only two papers out of 34 reporting linkage results.[40,41] As in existing frameworks, the terminology and application of some DQA practices among the included studies featured variable or inconsistent meanings. Several studies assessed similar data for similar purposes using different language and overlapping approaches, comparing (for example) prehospital documentation to in-hospital data, or continuously monitored vital signs to recorded values, in terms of either accuracy or reliability (or both).[52,93,94,97,111] While interpretation depends on the specific questions and data within studies, this variety highlights the need for clear and consistent terminology to support transparency and comparability in DQA practices.

These characteristics of DQA practices point to both the relative youth of research in paramedicine and continuing barriers to research and data collection in the field in general.[9,10] These barriers are discussed at length by several articles, and key findings reiterate the difficulty of collecting high-quality information (especially accurate demographic details) in the clinical environment.[42] Incomplete or unreliable data limit the effectiveness of deterministic linkage,[84] and inconsistent reporting of common data fields complicates studies using aggregated data. Problems with varied reporting were observed among a range of topic areas, including defining trauma calls,[84] coding chief complaints,[44] reporting OHCA variables,[71] and even the ages defining pediatric patients, which ranged among included studies from 0–4 to 0–21.[55,68,102,112] These inconsistencies overlapped with observed difficulties in both coding and extracting information from free-text data.[44,67] Data linkage is complex, labour-intensive, and expensive, presenting challenges to single services aiming to assess outcomes.[103] Finally, the need to establish data-sharing agreements between organizations that collaborate in patient care constitutes another barrier to outcome assessment.[84]

Although challenges to data quality were widely described, fewer studies remarked on strategies for assurance or improvement. Among those that did, Mann et al. referenced a system of over 300 logic rules that assess data quality prior to acceptance in NEMSIS.[46] (While logic rules are commonly applied, one paper observed the unintended consequence of a “bare minimum effect” when forcing documentation.[42]) Several studies showed improved documentation after focused and dedicated internal training.[63,67,113] Others noted improved outcomes with the introduction of electronic forms or databases.[114-116] Methodological refinements in case ascertainment, handling missing data, and linkage strategies were also shown to maximize data quality.[45,83,96]

Beyond the barriers and strategies for improvement for data quality in general, the included studies speak to DQA practices both by what they describe and by what they do not. Existing DQA frameworks feature domains and sub-domains that did not appear among the included studies. One example is the concept of temporal consistency.[25,117] Part of a general domain of consistency or reliability, temporal consistency assesses trends over time to look for deviations outside of expected ranges. Although several studies assessed agreement between data sources and the spread of repeated measures, and some examined data for outliers that would be considered invalid, temporal consistency as defined in this way did not appear. Temporal consistency could be particularly applicable to paramedic datasets – datasets that reflect patient care delivered within a dynamic work environment that must adapt to changing conditions and update protocols, procedures, and equipment in the course of continuing operations. In these environments, assessing data trends over time would function as a check for data influenced by changing system conditions that would not otherwise be noted by researchers.

Other examples of absent domains include broad categories such as accessibility, clarity, and timeliness.[25,26] These domains (as well as synonyms and related concepts such as punctuality, relevance, interpretability, comparability) largely reflect the needs of researchers in gaining access to databases, the timing of data updates and their availability, and supporting documentation (such as data dictionaries).[14,25,26] (Occasional studies have assessed the timeliness of the availability of the paramedic record for clinical use, but not for research purposes.[118,119]) The absence of these domains might be seen also to reflect the relative youth of paramedic databases and remaining barriers to incorporating them into administrative repositories.

Considering DQA along a spectrum of progress highlights current issues and how they might be incorporated into the next iterations of guidelines for paramedic data. Recent research has foregrounded comprehensive reporting of sex and gender and the inadequacy of binary options for sex as a single option to encompass a multi-dimensional concept.[120] Sex and gender reporting has been evaluated in other electronic health datasets,[121] and the implications of its limitations on record linkage were considered in one included study.[78] In a similar approach, the COVID-19 pandemic has offered opportunities to examine outcomes through a lens of data equity,[122] and current guidance on race-based data collection emphasizes a range of system features that might be considered preconditions for the responsible collection and use of this information.[123] Finally, knowledge of patient and public perspectives related to individual data items translates to awareness of public involvement and engagement in data management as a precursor to maintaining social license for healthcare research.[124,125] While concepts such as data ownership, stewardship, and patient and public involvement do not address quality in the same way as ensuring birthdates are collected accurately, they undoubtedly have a role in how data is collected, accessed, and used – and therefore a role in ensuring the most basic definition of data quality, that it is fit for use.[26]

LIMITATIONS

While comprehensive, the search strategy employed in this review was necessarily exploratory. It was iteratively refined to ensure capture of known key papers, but the possibility of missed articles cannot be excluded, and the resulting sample could be biased in unknown ways. Extreme heterogeneity among included studies presents difficulty in summarizing results. Alternative ways of categorizing and interpreting the data are possible, and the approach taken here potentially reflects biases among the reviewers. Although small, the review team included members with clinical, administrative, and methodological expertise in order to guard against this possibility. In keeping with the nature of scoping reviews, these results should be taken as a preliminary description of the field of study, with analyses and conclusions interpreted cautiously.

CONCLUSIONS

This scoping review of DQA practices in paramedic research summarizes diverse approaches applied largely as needed in individual studies or research programs. Although there are many opportunities and options for improving the quality of data collected at the source, the results of this review point to additional considerations for practice leaders. Databases of health information collected by paramedics would benefit from a standardized framework for DQA that allows for local variation while establishing common methods, terminology, and reporting standards. As paramedic research continues to grow, there is an opportunity to integrate progressive concepts of availability, stewardship, and ownership into emerging constructs.

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GENERAL DISCUSSION

Each individual paper contributes unique findings in its own area and to the general topic. The review of practice demonstrated a decreasing rate of treatment and changing patterns of care; attitudes of skepticism towards the value of treatment and tension between protocols and practice were expressed in the paramedic survey; and the scoping review described variable DQA practices and limits to area-specific research. Taken together, the findings of each paper relate to the others in ways that extend the discussion. In particular, the database review and the survey can be seen to metaphorically speak back and forth, connecting provider attitudes and practice. As one study confirms more practice variety in the data than can be explained by formal protocol changes, the other demonstrates that this variety reflects, in part, previously unmeasured and evolving attitudes towards the treatment itself. As paramedics describe balancing sometimes competing demands between following protocol and tailoring care to diverse patients, these concerns surface in the documented patterns of care delivered. While a necessary precursor to further study, the scoping review of data quality assessment practices in research in paramedicine connects to paramedics' expressed knowledge of research findings and foregrounds questions of data quality in this specific clinical area. This awareness highlights the strengths and weaknesses not only of the data used in this thesis, but also of related literature.

Informed by the collected results, Figure 5.1 displays a substantially revised version of the conceptual model of the treatment of potential spine injuries in the prehospital setting and the role of data in studying it.

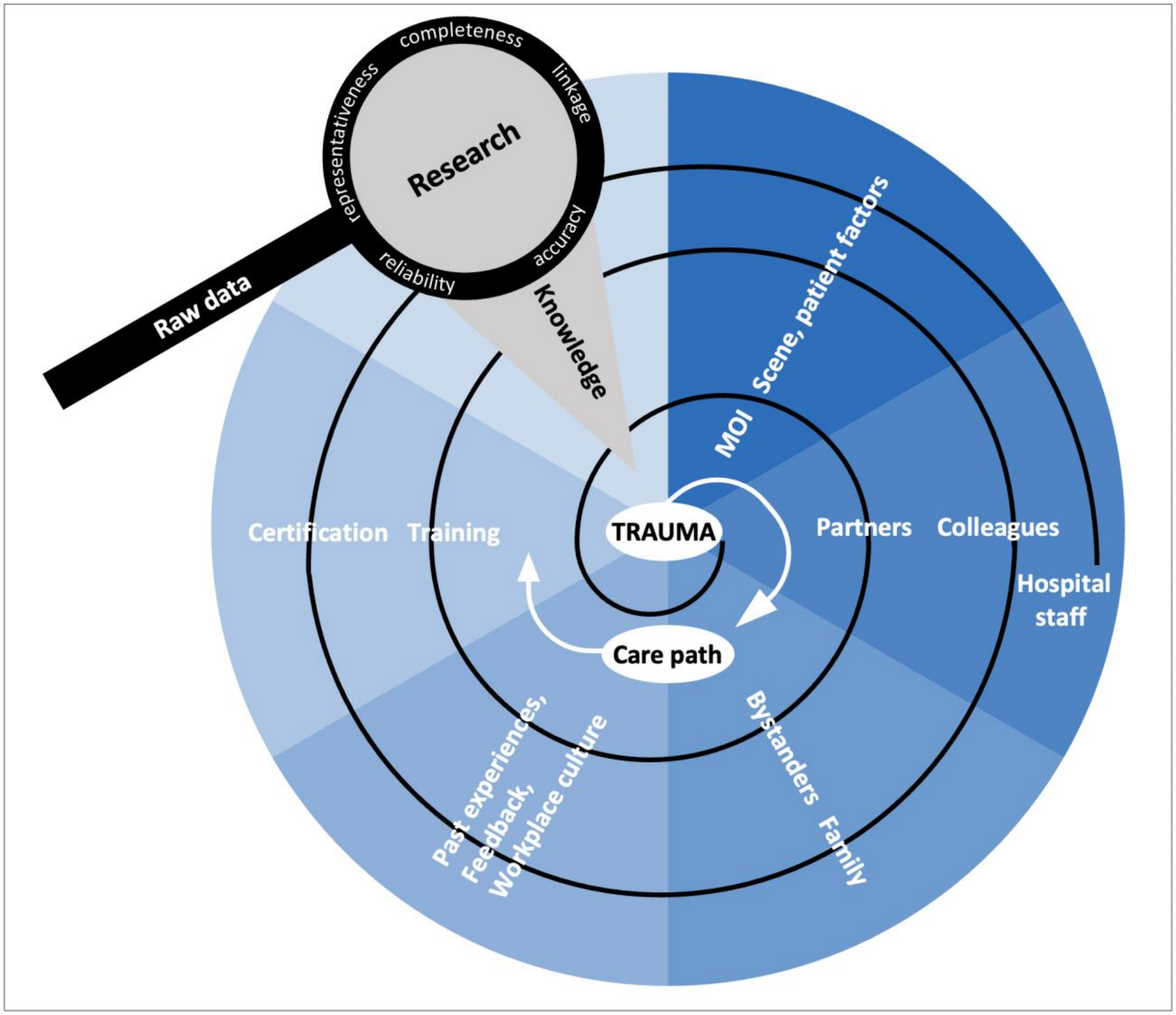

Figure 5.1: Decision-making in the prehospital treatment of patients with potential spine injuries. Figure represents the path of patient care as a spiral bounded by protocol, with influences on practice in the background and new knowledge illuminated by a research lens breaking into the spiral.
MOI, mechanism of injury.

In this figure, the spiral represents the patient's clinical pathway. The path is defined and delineated by lines representing formal protocols, but the space between the lines represents leeway or wiggle-room for variations in care within these boundaries – variations described by survey respondents in their reflections on practice (survey study, content analysis) and seen in changing patterns of cervical-collar use and alternative positioning (database study, Tables 1.3 & 1.4).

Literature on prehospital decision-making (as in the emergency department), confirms that this process is not linear and straight-forward, but dynamic, subject to constant revision, and influenced by a range of factors.[76,77] As aids in the process, clinical decision rules perform less as yes/no algorithms than as a cognitive scaffold or source of guidance used in relation to a provider's level of comfort and experience.[76-78] In the updated figure, a spiral has replaced a flowchart to represent this knowledge. Here, decisions are made and revised in the context of multiple influences and changing information, and the clinical decision rule has disappeared as a distinct step happening at one moment; it has been subsumed into a process of information-gathering that varies by time and context.

The shaded backgrounds represent influences on clinical care. These include traditional elements of flowchart decision-making, such as the mechanism of injury and patient factors from the clinical exam. They also include a broader interpretation of patient and scene factors informed by survey respondents and prior literature: patient age, anatomy, clothing, and behaviour[53,79]; scene characteristics such as positioning, a need for extrication, and weather[80]; and transport considerations such as vehicle type, duration, and expected changes or interventions en route.[52,81] Additionally, these influence include input from partners and colleagues, as well as factors described by survey respondents: training, past experiences, workplace culture and expectations, and new knowledge (survey study, Table 2.6). (Some of these elements are present in recent international guidelines from New Zealand and the United Kingdom.[82,83] In the case of New Zealand in particular, the pathway for cervical spine immobilization tests the limits of a flowchart format: it includes multiple branching options, each one with treatments that are either specified or listed as options for consideration.[82] This layout represents the process less as predetermined and sequential and more as iterative, ongoing, and adaptable to circumstance.)

The widening spiral represents information gradually accumulating (ranging from immediate and specific to more general and reflective), and the narrowing path represents diminishing options for alternative treatment during the course of the call. The spiral can be broken by the introduction of new knowledge generated and illuminated through the lens of research. In this part of the figure, the handle of raw data supports the lens, which is itself given shape and structure by common data quality domains defining its border, focusing the research output. In this way, the spiral represents not only the path of any individual call, but also the integration of new knowledge into practice over time. Based on the position of the lens, we can see that research is currently closest to key elements: decision points related to mechanism of injury, the treatment pathway, transport, and ongoing training and certification. It is more remote from paramedics’ past experiences and feedback (which also accumulate in influence), input from other providers (including hospital staff), and is farthest from the perspectives of the public.

PRACTICAL IMPLICATIONS & FUTURE RESEARCH DIRECTIONS

Most immediately, the results of this thesis will provide methodological guidance to continuing work on linking prehospital and in-hospital data. This work will be an essential part of informing future practice guidelines by underpinning treatment recommendations with robust outcome data applicable to the local setting. Although those results are not yet known, the direction of change can be anticipated.

Findings from both the database study and the survey demonstrate that paramedics work within protocols to adapt treatments to individual patients when possible. Future guidelines should continue in this direction by involving frontline providers in protocol development and formalizing a wider selection of treatment options. Ideal treatments will vary for patients among any number of possible presentations (from high-risk to low-risk, from frail geriatric to agitated intoxicated) in any number of circumstances (from difficult extrications to long transports). Alternative treatments already in use or contemplated across international jurisdictions include restricting backboard use to extrication (not transport), full-body immobilization with a vacuum mattress, lateral positioning, semi-Fowler's positioning, soft head blocks, soft collars, removal of cervical collars, and the option to signal the potential for a spine injury with a lanyard around a patient's neck without applying further treatment.[15,82,84,85] The ideal mix of prescribed options and improvised alternatives will depend on the conditions of individual settings and engagement with stakeholders. Successful change-implementation programs in this area have demonstrated the importance of broad-based engagement,[57] but patient-public involvement (as represented by the position of research in Figure 5.1) remains scant.[86,87]

Within these treatment options, there will be continuing opportunities to research and refine ideal methods of motion restriction in a range of circumstances. There is no current consensus on how to best adapt existing devices to modified positions or patient needs. As well, there is increasing (not decreasing) debate about the type of motion that could potentially cause additional traumatic injury.[88,89] Addressing these questions will likely require additional biomechanical analysis (perhaps supplemented with advanced computational modelling[90]) in combination with linked outcome data for spine-injured patients.

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APPENDICES

Appendix 1.1, "Mechanisms of injury"

Table: Mechanism of injury of all patients treated with spinal immobilization / spinal motion restriction, 2009 - 2020

All cells reported as n (%) except where indicated: Cases, Mean annual percent change (95% CI)

	Cases	Falls	MVA	Assault	Sports	Other	Not reported
Total	25747	5886 (23)	5913 (23)	3737 (15)	514 (2.0)	173 (0.7)	9524 (37)
2009 (04-12)	3417	971 (28)	818 (24)	621 (18)	72 (2.1)	20 (0.6)	915 (27)
2010	3652	890 (24)	835 (23)	602 (17)	88 (2.4)	28 (0.8)	1209 (33)
2011	3007	669 (22)	739 (25)	482 (16)	50 (1.7)	25 (0.8)	1042 (35)
2012	2985	675 (23)	688 (23)	439 (15)	51 (1.7)	29 (1.0)	1103 (37)
2013	2337	486 (21)	575 (25)	289 (12)	65 (2.8)	15 (0.6)	907 (39)
2014	1938	439 (23)	449 (23)	228 (12)	43 (2.2)	16 (0.8)	763 (39)
2015	1686	349 (21)	422 (25)	184 (11)	24 (1.4)	8 (0.5)	699 (42)
2016	1622	334 (21)	348 (22)	191 (12)	32 (2.0)	7 (0.4)	710 (44)
2017	1632	336 (21)	351 (22)	240 (15)	42 (2.6)	7 (0.4)	656 (40)
2018	1603	333 (21)	317 (20)	204 (13)	24 (1.5)	7 (0.4)	718 (45)
2019	1651	362 (22)	325 (20)	237 (14)	18 (1.1)	10 (0.6)	699 (42)
2020 (01-02)	217	42 (19)	46 (21)	20 (9.2)	5 (2.3)	1 (0.5)	103 (48)
Mean annual percent change (95% CI)		-2.6*** (-3.4, -1.8)	-1.5*** (-2.3, -0.7)	-3.6*** (-4.6, -2.6)	-2.6 (-5.3, 0.1)	-4.4 (-9.0, 0.3)	4.1*** (3.5, 4.8)

*P values: * < 0.05, ** < 0.01, *** < 0.001*
MVA, motor vehicle accident

Appendix 1.2, "Treatment indications"

Table: Documented indications for treatment for all cases of spinal precautions, 2009 - 2020

All cells reported as n (%) except where indicated: Cases, Mean annual percent change (95% CI)

	Total	Apr. - Dec. 2009	2010	2011	2012*	2013	2014	2015	2016	2017	2018	2019	Jan. - Feb. 2020	Mean annual percent change (95% CI)	p
Cases	25747	3417	3652	3007	2985	2337	1938	1686	1622	1632	1603	1651	217		
"Indications" field selected*	21243 (82)	1877 (55)	2265 (62)	2001 (67)	2589 (87)	2304 (98.6)	1909 (98.5)	1656 (98.2)	1594 (98.3)	1605 (98.3)	1587 (99.0)	1639 (99.3)	217 (100)		
Indications: any instance															
GCS < 15	6888 (32)	678 (36)	800 (35)	637 (32)	673 (26)	713 (31)	623 (33)	558 (34)	526 (33)	536 (33)	538 (34)	543 (33)	63 (29)	-0.02 (-0.77, 0.74)	>0.9
Head trauma	12347 (58)	1170 (62)	1441 (64)	1208 (60)	1493 (58)	1257 (55)	1014 (53)	924 (56)	882 (55)	886 (55)	910 (57)	1045 (64)	117 (54)	-0.69 (-1.2, -0.12)	0.02
Intoxication	7722 (36)	773 (41)	857 (38)	741 (37)	910 (35)	800 (35)	666 (35)	615 (37)	567 (36)	574 (36)	565 (36)	590 (36)	64 (30)	-0.97 (-1.7, -0.26)	0.008
Distract. injury	5141 (24)	462 (25)	529 (23)	516 (26)	650 (25)	538 (23)	441 (23)	419 (25)	350 (22)	358 (22)	383 (24)	432 (26)	63 (29)	0.01 (-0.86, 0.89)	>0.9
Spine tender.	8050 (38)	573 (31)	811 (36)	774 (39)	1080 (42)	896 (39)	804 (42)	630 (38)	648 (41)	642 (40)	561 (35)	547 (33)	84 (39)	0.36 (-0.34, 1,1)	0.3
Neuro. deficit	1426 (6.7)	96 (5.1)	143 (6.3)	125 (6.2)	192 (7.4)	152 (6.6)	143 (7.5)	133 (8.0)	109 (6.8)	108 (6.7)	103 (6.5)	110 (6.7)	12 (5.5)	1.3 (-0.4, 3.0)	0.1
Indications: only instance															
GCS < 15	394 (1.9)	39 (2.1)	49 (2.2)	42 (2.1)	30 (1.2)	40 (1.7)	40 (2.1)	34 (2.1)	27 (1.7)	31 (1.9)	41 (2.6)	21 (1.3)	0 (0)	-1.2 (-4.3, 1.9)	0.4
Head trauma	1739 (8.2)	210 (11)	216 (9.5)	203 (10)	206 (8.0)	160 (6.9)	112 (5.9)	110 (6.6)	116 (7.3)	108 (6.7)	130 (8.2)	153 (9.3)	15 (6.9)	-3.1 (-4.5, -1.6)	<0.001
Intoxication	386 (1.8)	36 (1.9)	31 (1.4)	24 (1.2)	41 (1.6)	35 (1.5)	26 (1.4)	41 (2.5)	41 (2.6)	39 (2.4)	37 (2.3)	30 (1.8)	5 (2.3)	5.1 (1.9, 8.5)	0.002
Distract. injury	898 (4.2)	70 (3.7)	84 (3.7)	70 (3.5)	114 (4.4)	103 (4.5)	78 (4.1)	79 (4.8)	61 (3.8)	72 (4.5)	72 (4.5)	86 (5.2)	9 (4.1)	2.7 (0.6, 4.8)	0.01
Spine tender.	2931 (14)	196 (10)	275 (12)	288 (14)	391 (15)	342 (15)	291 (15)	242 (15)	258 (16)	239 (15)	196 (12)	175 (11)	38 (18)	0.6 (-0.5, 1.8)	0.3
Neuro. deficit	67 (0.3)	8 (0.4)	5 (0.2)	5 (0.2)	7 (0.3)	4 (0.2)	10 (0.5)	5 (0.3)	4 (0.3)	8 (0.5)	5 (0.3)	6 (0.4)	0 (0)	2.2 (-5.4, 10)	0.6
Indications: number recorded															
0	1732 (8.2)	122 (6.5)	129 (5.7)	130 (6.5)	239 (9.2)	264 (12)	184 (9.6)	136 (8.2)	130 (8.2)	132 (8.2)	123 (7.8)	118 (7.2)	25 (12)	1.7 (0.2, 3.2)	0.03
1	6415 (30)	559 (30)	660 (29)	632 (32)	789 (31)	684 (30)	557 (29)	511 (31)	507 (32)	497 (31)	481 (30)	471 (29)	67 (31)	0.07 (-0.71, 0.85)	0.9
2	6475 (31)	589 (31)	752 (33)	587 (29)	767 (30)	647 (28)	583 (31)	460 (28)	472 (30)	497 (31)	524 (33)	539 (33)	58 (27)	0.15 (-0.62, 0.93)	0.7
3	4685 (22)	443 (24)	526 (23)	452 (23)	551 (21)	498 (22)	407 (21)	382 (23)	340 (21)	340 (21)	334 (21)	362 (22)	50 (23)	-0.72 (-1.6, 0.2)	0.1
4	1581 (7.4)	139 (7.4)	155 (6.8)	165 (8.2)	199 (7.7)	175 (7.6)	150 (7.9)	136 (8.2)	118 (7.4)	109 (6.8)	99 (6.2)	121 (7.4)	15 (6.9)	-0.74 (-2.3, 0.84)	0.4
5	300 (1.4)	20 (1.1)	39 (1.7)	31 (1.5)	38 (1.5)	32 (1.4)	21 (1.1)	28 (1.7)	23 (1.4)	23 (1.4)	23 (1.4)	20 (1.2)	2 (0.9)	-0.65 (-4.2, 3.0)	0.7
6	55 (0.3)	5 (0.3)	4 (0.2)	4 (0.2)	6 (0.2)	4 (0.2)	7 (0.4)	3 (0.2)	4 (0.3)	7 (0.4)	3 (0.2)	8 (0.5)	0 (0)	6.0 (-2.6, 15)	0.2

*Mandatory documentation of indications implemented in mid 2012. *GCS, Glasgow Coma Scale*

Appendix 2.1, "Final Survey"

Survey

Paramedic attitudes towards prehospital treatment of potential spine injuries

1. Please confirm you are a licensed paramedic practicing with the Winnipeg Fire Paramedic Service. This survey is open only to current WFPS paramedics.
    a. I am a licensed paramedic with the Winnipeg Fire Paramedic Service
    b. I am not a licensed paramedic with the Winnipeg Fire Paramedic Service and will exit the survey.

2. What is your current qualification level / role?
    a. PCP/FFPCP
    b. ICP
    c. ACP/ACP-P
    d. DC/TO/PCPO

3. Please enter the number of years you have been practicing as a paramedic (as a number, rounded to the nearest year). Enter 0 if you are not a practicing paramedic.
    a. [free text for number]

4. Age [free text for number]

5. Gender
    a. Woman
    b. Man
    c. Transgender
    d. Non-binary/non-conforming
    e. Prefer not to respond

Section 1:
General Attitudes

This survey investigates paramedics' attitudes and practice around the use of spinal precautions. Formerly known as "spinal immobilization", these practices are more generally referred to as spinal motion restriction (SMR). This survey will use the term "SMR" to refer to all treatment (collar-only or board-and-collar) and "Spinal Immobilization" only when specifically referring to the intervention tab in the ePCR.

1.1 In your opinion, how effectively does SMR as currently practiced limit patient motion?
<- Not at all effectively … Very effectively ->

1.2 In your estimation, how often have you observed SMR *ineffectively* limit motion or cause more motion than no treatment or alternatives?
<- Very infrequently … Very frequently ->

1.3 Among patients at risk for spine injury and in SMR, how often do you observe patient motion that you feel could potentially cause further harm to their spine?
<- Very infrequently … Very frequently ->

1.4 In your opinion, could your service's current SMR protocols be changed to more effectively limit motion?
<- No, not at all … Yes, very much so ->

1.5 If your service's SMR could be improved, how would you like to change it (check all that apply)?
a. No change
b. Different assessment protocol / more leeway in choosing when to apply SMR
c. More options in terms of devices / patient positioning
d. Option not to apply any devices (including a cervical collar)
e. Other (free text)

1.6 If your service's SMR could be improved, which patient groups, if any, would benefit from modified or special treatment. (check all that apply)?
a. None
b. Geriatrics
c. Pediatrics
d. Intoxicated
e. Agitated / combative
f. Other (free text)

1.7 Do you feel you have been treating fewer or more patients with SMR over during your time in EMS?
<- Many fewer … Many more ->

1.8 Do you feel SMR is seen as less or more important than it was in the past?
<- Much less … Much more ->

1.9 If you feel there is a reason for a change in your practice over time, please explain: (short answer)

Section 2:
Specific Attitudes

2.1 In your opinion, how effectively does a cervical collar restrict head motion in a potentially spine-injured patient?

<- Not at all effectively … Very effectively ->

2.2 How often have you observed complications of a cervical collar resulting in more patient movement than no treatment or alternative / improvised treatment.

<- Very infrequently … Very frequently ->

2.3 Among patients at risk for spine injury and in a cervical collar, how often do you observe patient movement that you feel could potentially cause further harm to their spine?

<- Very infrequently … Very frequently ->

2.4 What size cervical collar do you apply most often?

a. No neck
b. Short
c. Medium
d. Tall
e. Improvised

2.5 How often do you measure a patient's neck to select a cervical collar?

<- Very infrequently … Very frequently ->

2.6 If you do not very frequently/always measure, which explanation best explains why:

a. Not applicable: I very frequently/always measure
b. It doesn't make a difference / I don't care
c. I would like to, but don't have time / don't have different sized collars
d. I intentionally apply shorter collars for patient comfort
e. Other (free text)

2.7 When treating a patient with isolated penetrating trauma to the head, neck, or torso, how often do you apply spinal precautions.

<- Very infrequently … Very frequently ->

2.8 When treating a patient with a known or suspected traumatic brain injury for whom spinal precautions are also indicated, how often do you loosen or remove a cervical collar?

<- Very infrequently … Very frequently ->

2.9 If a standard collar does not seem appropriate for a patient (due to usual anatomy or extremes of age, for example), how often would you apply an improvised collar such as a towel roll?

<- Very infrequently … Very frequently ->

2.10 If a patient is actively fighting against treatment devices (c-collar, straps, head blocks), how often would you remove, loosen, or modify the devices?

<- Very infrequently … Very frequently ->

2.11 For patients who require spinal precautions but are actively vomiting, how often would you secure them in the lateral / recovery position as opposed to rolling them each time they vomit?

<- Very infrequently … Very frequently ->

2.12 How often do you secure an SMR patient in a position other than supine?

<- Very infrequently … Very frequently ->

2.13 If you do not very frequently/always position your patient supine, which other position do you use most frequently?

a. Not applicable: always supine
b. Lateral
c. Semi-Fowler's
d. Sitting
e. Other

Section 3:
Spinal assessment protocols

3.1 In general, how often do you follow the criteria of the c-spine management protocol to determine the need for SMR in the setting of trauma with the potential for spine injury?

<- Very infrequently … Very frequently ->

3.2 In general and in your opinion, would you rate your service's criteria for determining the need for spinal precaution as <u>not restrictive enough</u> (patients left untreated who need it) or <u>too restrictive</u> (too many patients treated who do not need it)?

<- Not restrictive enough … Too restrictive ->

3.3 Do you ever use spinal precautions when they are not indicated by protocol?

<- Very infrequently … Very frequently ->

3.4 In which cases would you opt to use spinal precautions when they are not indicated by protocol (check all that apply)?

a. Not applicable: I never use them when not indicated by protocol
b. Believe they are necessary / protocol is not sufficient
c. Instructed by senior provider to do so
d. Worried about liability / opinion of receiving facility
e. Precautions already placed by other providers
f. Other (free text)

3.5 Do you ever not use spinal precautions when they are indicated by protocol for reasons other than refusal?

<- Very infrequently … Very frequently ->

3.6 In which cases would you opt not to use spinal precautions when indicated by protocol (other than cases of refusal, check all that apply)?

a. Not applicable: I always use them when indicated by protocol
b. Don't believe they are necessary / protocol is too restrictive
c. Could potentially cause harm to this patient
d. Find an alternative technique.
e. Other (free text)

Section 4:
Judging MOIs

WFPS documentation uses a closed-call rule to prompt users to consider the c-spine management protocol in all trauma cases. The first field asks providers to categorize the mechanism of injury as either having no potential for spine injury (allowing users to exit the protocol) or the potential for spine injury (requiring assessment).

How would you document the following mechanisms of injury?

4.1 An adult, unrestrained car passenger, ejected after a crash at 100km/hr.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.2 Young adult, playing soccer, rolls over on ankle. No trauma to head. No contact with other players.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.3 Adult, assaulted. Punched in the face. No weapons used. Fell to the ground.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.4 Adult, tripped while walking. Fell on out-stretched arm. Complaining of shoulder pain. No trauma to the head.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.5 Adult, tripped coming down stairs. Fell to the ground from one step.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.6 Adult, fall from standing. Laceration to the face. No loss of consciousness.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.7 Elderly adult (>65). Fall from standing. Laceration to the face. No loss of consciousness.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.8 Elderly adult (>65), assaulted. Punched in the face. No weapons. Fell to the ground.
   a. Trauma w/ No Potential for C-Spine Injury
   b. Trauma w/ Potential for C-Spine Injury

4.9 Adult, restrained driver, MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.

a. Trauma w/ No Potential for C-Spine Injury
b. Trauma w/ Potential for C-Spine Injury

4.10 Child (7 years old), restrained on a booster seat on the driver's side, rear. MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.

a. Trauma w/ No Potential for C-Spine Injury
b. Trauma w/ Potential for C-Spine Injury

4.11 Elderly adult (>65). Syncopal episode. Fall from standing.

a. Trauma w/ No Potential for C-Spine Injury
b. Trauma w/ Potential for C-Spine Injury

4.12 Child (8 years old), fall from a slide onto grass, 2 meters. Hit head. Unknown if there was a loss of consciousness.

a. Trauma w/ No Potential for C-Spine Injury
b. Trauma w/ Potential for C-Spine Injury

4.13 In general, if you feel that a mechanism of injury is uncertain for its potential to cause a spine injury, what do you do?

a. Choose "Trauma w/ No Potential for C-Spine Injury" and assess for and treat other problems.
b. Choose "Trauma w/ Potential for C-Spine Injury", assess by protocol and treat according to assessment findings.
c. Defer to your partner or another provider
d. Other (free text)

Section 4:
Documentation

The following questions were included in the survey, but have been analyzed separately and are not considered in this paper.

4.14 When you have treated your patient with spinal precautions, how frequently do you use the “Spinal Immobilization” intervention in the ePCR to document it?
1-very infrequently/never, 2-infrequently 3-about half the time, 4-frequently, 5-very frequently/always

4.15 When using the “Spinal Immobilization” intervention, how frequently would you say the intervention is time-stamped within 15 minutes of when it actually occurred?
1-very infrequently/never, 2-infrequently 3-about half the time, 4-frequently, 5-very frequently/always

The remaining questions refer to this scenario:

You are called by police to assess and adult male who was assaulted. On arrival, you find a grown man sitting on the curb. He shows signs of being intoxicated and has an empty bottle of alcohol in his pocket. You see a fresh laceration on his forehead that is oozing blood. When you ask the patient if anything is wrong, he says: “I’m short of breath. I can’t breathe.” The patient has no other complaints, no other physical findings, no signs of drug use other than alcohol, and vital signs all within normal ranges.

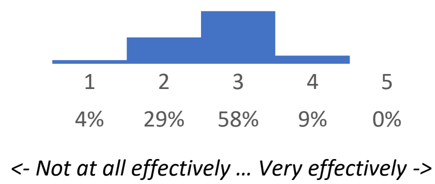
4.16 How would you document this patient’s Chief Complaint?
a. Substance misuse
b. Assault OR head injury OR head pain
c. Shortness of breath
d. Other

4.17 How would you document your Primary Impression for this patient?
a. Substance misuse (alcohol)
b. Any Trauma impression
c. Respiratory (other respiratory problem)
d. Other

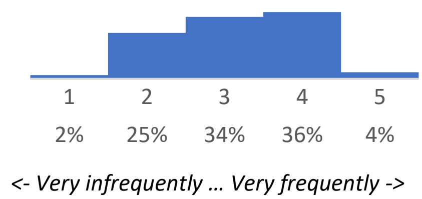
4.18 How would you document this patient’s initial CTAS Category and Chief Complaint?
a. Respiratory – Shortness of Breath
b. Neurology – Head Injury OR Trauma – any complaint
c. Substance Misuse – Substance Abuse / Intoxication
d. Other

Appendix 2.2, "Raw survey data"

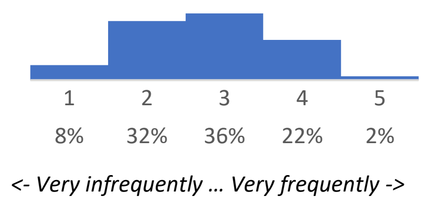
1.1 In your opinion, how effectively does SMR as currently practiced limit patient motion?



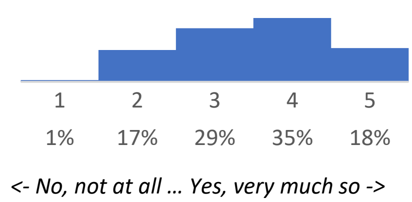
1.2 In your estimation, how often have you observed SMR ineffectively limit motion or cause more motion than no treatment or alternatives?



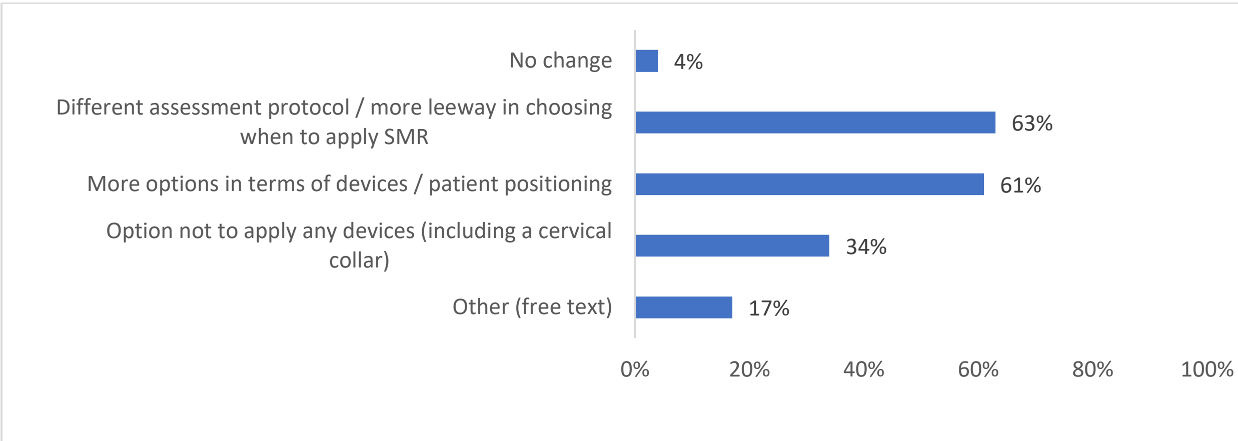
1.3 Among patients at risk for spine injury and in SMR, how often do you observe patient motion that you feel could potentially cause further harm to their spine?



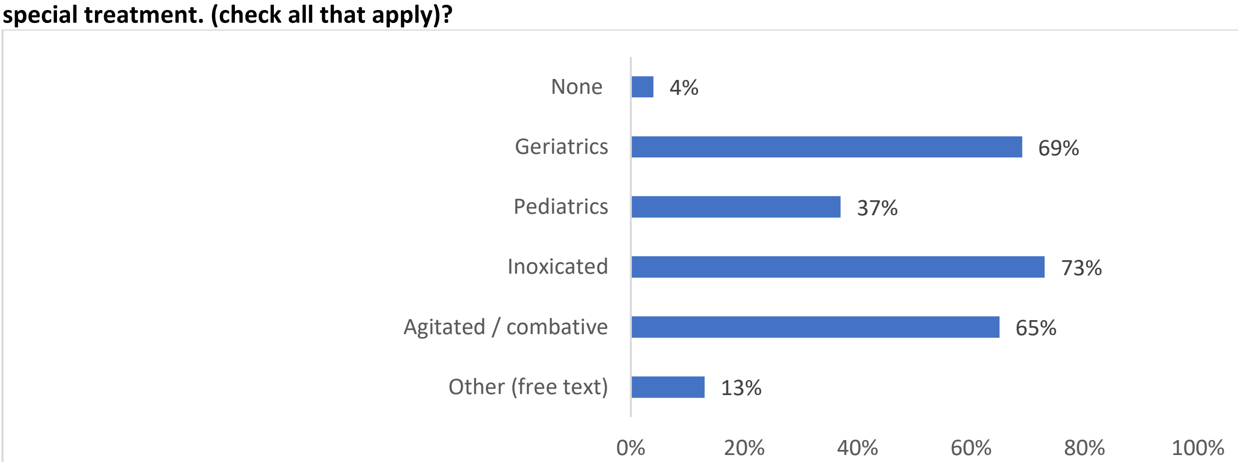
1.4 In your opinion, could your service's current SMR protocols be changed to more effectively limit motion?



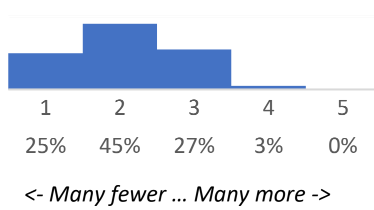
1.5 If your service's SMR could be improved, how would you like to change it (check all that apply)?



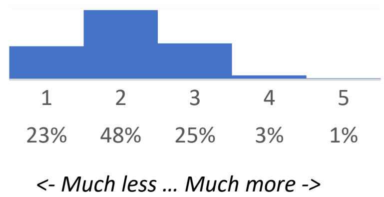
1.6 If your service's SMR could be improved, which patient groups, if any, would benefit from modified or special treatment. (check all that apply)?



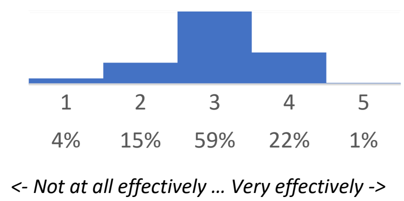
1.7 Do you feel you have been treating fewer or more patients with SMR over during your time in EMS?



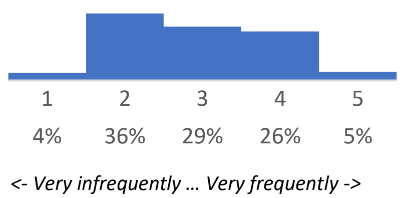
1.8 Do you feel SMR is seen as less or more important than it was in the past?



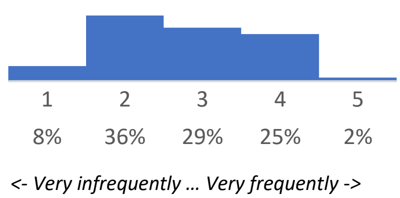
2.1 In your opinion, how effectively does a cervical collar restrict head motion in a potentially spine-injured patient?



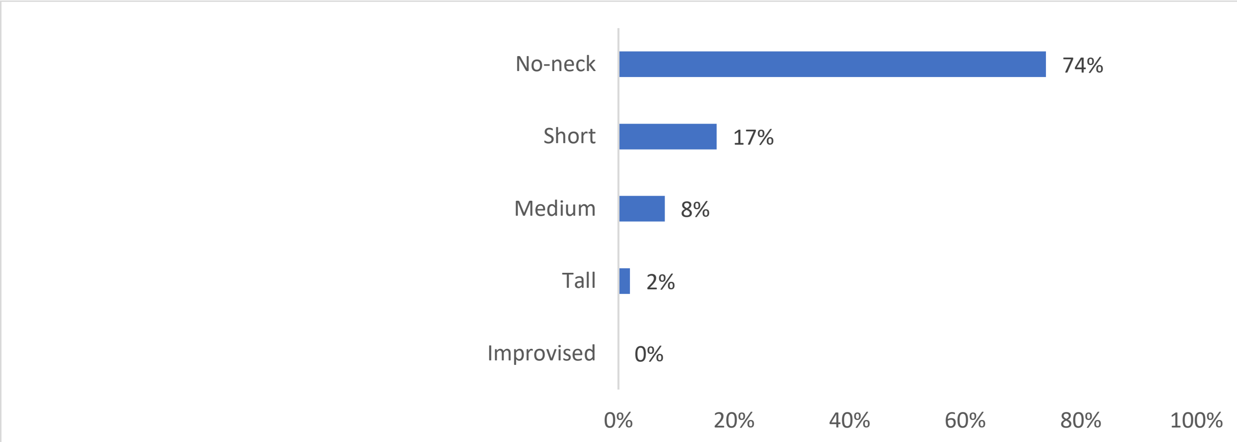
2.2 How often have you observed complications of a cervical collar resulting in more patient movement than no treatment or alternative / improvised treatment.



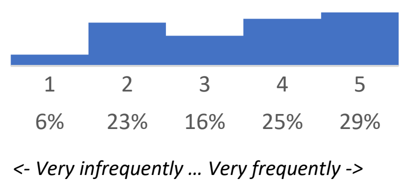
2.3 Among patients at risk for spine injury and in a cervical collar, how often do you observe patient movement that you feel could potentially cause further harm to their spine?



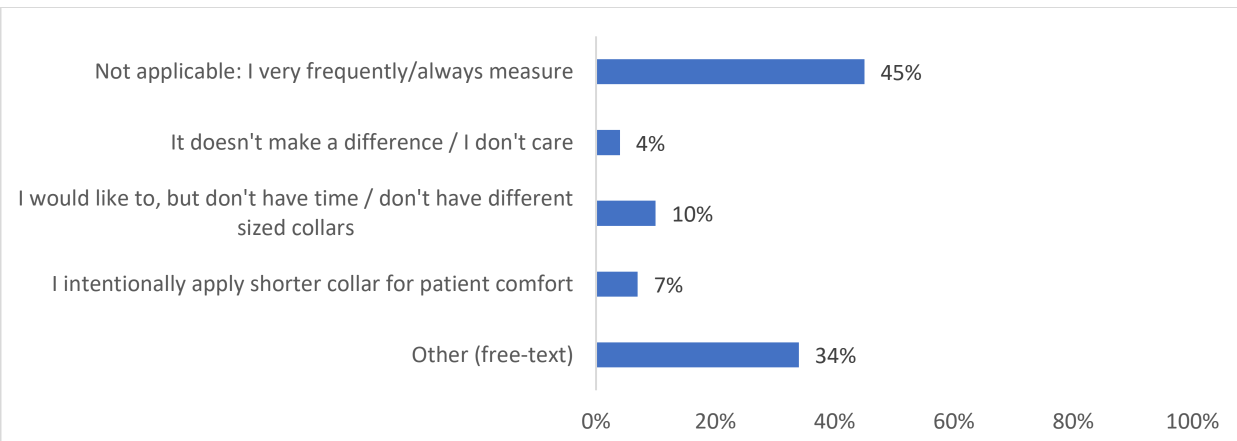
2.4 What size cervical collar do you apply most often?



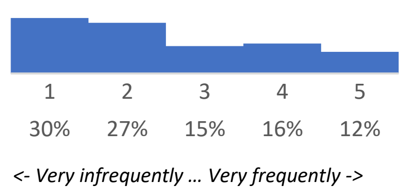
2.5 How often do you measure a patient's neck to select a cervical collar?



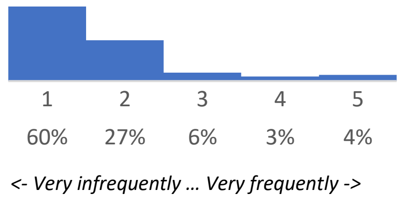
2.6 If you do not very frequently/always measure, which explanation best explains why:



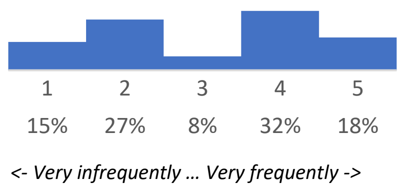
2.7 When treating a patient with isolated penetrating trauma to the head, neck, or torso, how often do you apply spinal precautions.



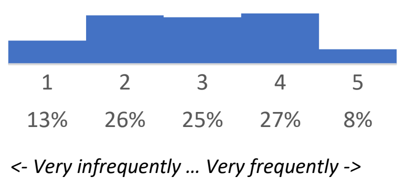
2.8 When treating a patient with a known or suspected traumatic brain injury for whom spinal precautions are also indicated, how often do you loosen or remove a cervical collar?



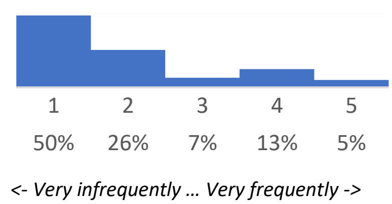
2.9 If a standard collar does not seem appropriate for a patient (due to usual anatomy or extremes of age, for example), how often would you apply an improvised collar such as a towel roll?



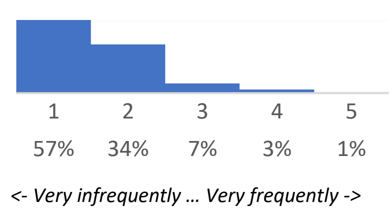
2.10 If a patient is actively fighting against treatment devices (c-collar, straps, head blocks), how often would you remove, loosen, or modify the devices?



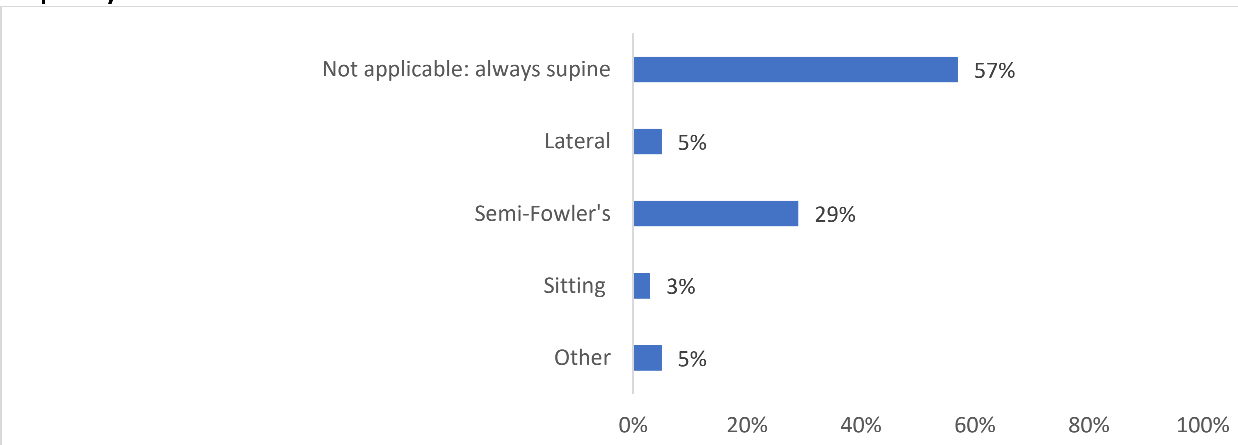
2.11 For patients who require spinal precautions but are actively vomiting, how often would you secure them in the lateral / recovery position as opposed to rolling them each time they vomit?



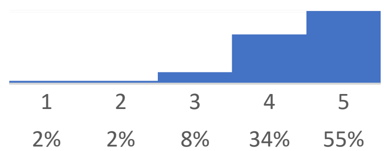
2.12 How often do you secure an SMR patient in a position other than supine?



2.13 If you do not very frequently/always position your patient supine, which other position do you use most frequently?

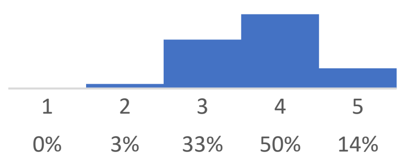


3.1 In general, how often do you follow the criteria of the c-spine management protocol to determine the need for SMR in the setting of trauma with the potential for spine injury?



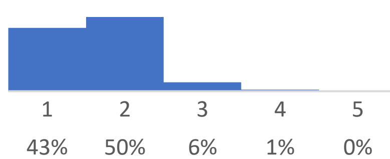
<- Very infrequently … Very frequently ->

3.2 In general and in your opinion, would you rate your service's criteria for determining the need for spinal precaution as not restrictive enough (patients left untreated who need it) or too restrictive (too many patients treated who do not need it)?



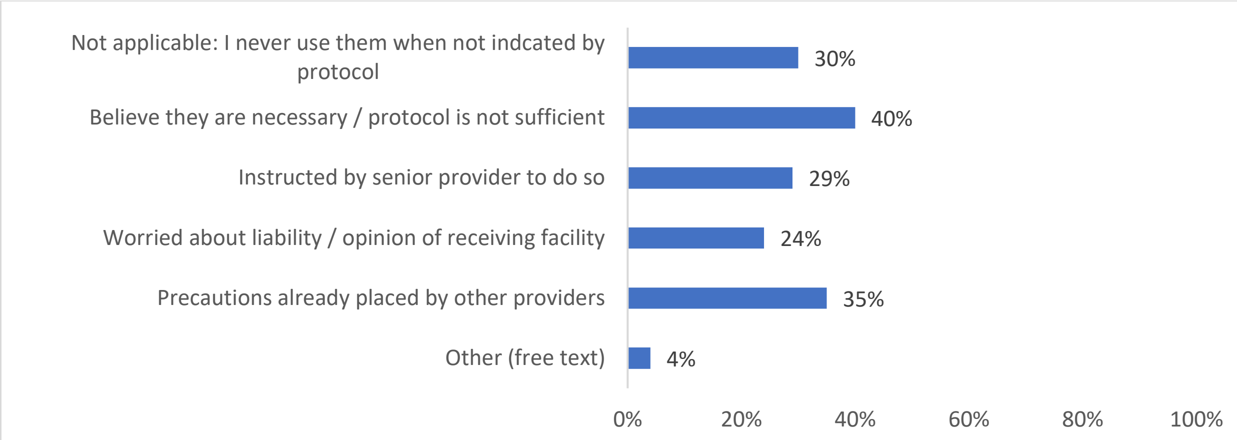
<- Not restrictive enough … Too restrictive ->

3.3 Do you ever use spinal precautions when they are not indicated by protocol?

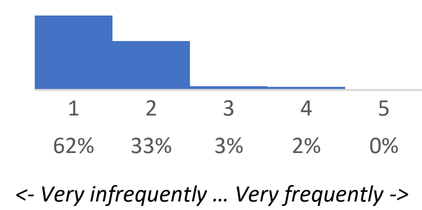


<- Very infrequently … Very frequently ->

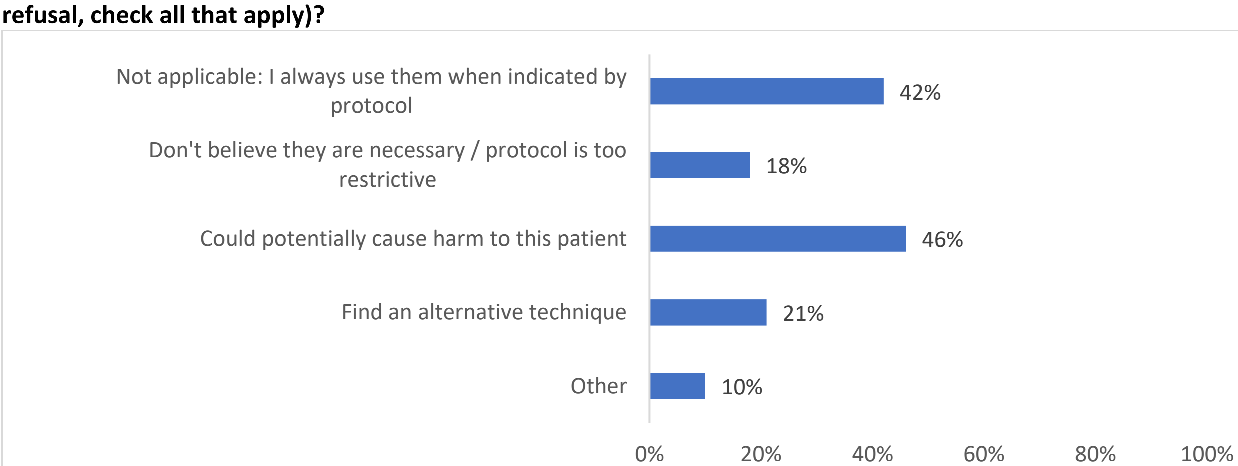
3.4 In which cases would you opt to use spinal precautions when they are not indicated by protocol (check all that apply)?



3.5 Do you ever NOT use spinal precautions when they are indicated by protocol for reasons other than refusal?



3.6 In which cases would you opt not to use spinal precautions when indicated by protocol (other than cases of refusal, check all that apply)?



4.1 An adult, unrestrained car passenger, ejected after a crash at 100km/hr.

Potential for spine inj.	100%
No potential for spine inj.	0%

4.2 Young adult, playing soccer, rolls over on ankle. No trauma to head. No contact with other players.

Potential for spine inj.	1%
No potential for spine inj.	99%

4.3 Adult, assaulted. Punched in the face. No weapons used. Fell to the ground.

Potential for spine inj.	53%
No potential for spine inj.	47%

4.4 Adult, tripped while walking. Fell on out-stretched arm. Complaining of shoulder pain. No trauma to the head.

Potential for spine inj.	3%
No potential for spine inj.	97%

4.5 Adult, tripped coming down stairs. Fell to the ground from one step.

Potential for spine inj.	25%
No potential for spine inj.	75%

4.6 Adult, fall from standing. Laceration to the face. No loss of consciousness.

Potential for spine inj.	19%
No potential for spine inj.	81%

4.7 Elderly adult (>65). Fall from standing. Laceration to the face. No loss of consciousness.

Potential for spine inj.	61%
No potential for spine inj.	39%

4.8 Elderly adult (>65), assaulted. Punched in the face. No weapons. Fell to the ground.

Potential for spine inj.	74%
No potential for spine inj.	26%

4.9 Adult, restrained driver, MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.

Potential for spine inj.	79%
No potential for spine inj.	21%

4.10 Child (7 years old), restrained on a booster seat on the driver's side, rear. MVC while turning left. Hit by a vehicle travelling 40 - 50 km/hr on the passenger side. Moderate damage at point of impact. Front air-bags deployed. Windshield intact.

Potential for spine inj.	79%
No potential for spine inj.	21%

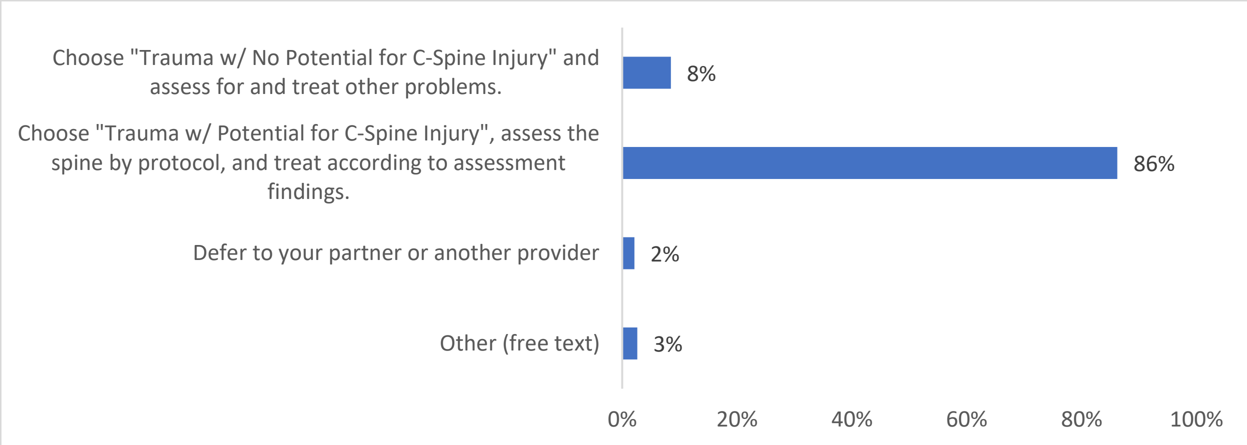
4.11 Elderly adult (>65). Syncopal episode. Fall from standing.

Potential for spine inj.	51%
No potential for spine inj.	49%

4.12 Child (8 years old), fall from a slide onto grass, 2 meters. Hit head. Unknown if there was a loss of consciousness.

Potential for spine inj.	91%
No potential for spine inj.	9%

4.13 In general, if you feel that a mechanism of injury is uncertain for its potential to cause a spine injury, what do you do?



Appendix 2.3, "Free-text responses"

Table: Free text responses by question

Number of entries (% of total respondents)	Categories	Sub-categories	Count of mentions (% responses to question)[1]	Illustrative Quotation(s)[2]
1.5: If your service's SMR could be improved, how would you like to change it?				
34 (17)	Treatment improvements	Different devices; fewer devices; medications; other positioning.	17 (50)	*Use of a lanyard to indicate c-spine not 'cleared' in patients requiring further assessment but not displaying any signs of spinal cord injury or severe midline neck pain*
	SMR causes motion	Collars uncomfortable; long backboard uncomfortable; patient movement worse when supine, when intoxicated, during transport.	11 (32)	*Hard collars only seem to provide discomfort [to] patients. Repeatedly moving and fighting the collar results in more movement, rendering the whole process redundant.*
	Adverse effects of treatment	Increased ICP; tissue damage	6 (18)	*[use] soft collars instead of hard [because of increasing] ICP secondary to compressed external jugular veins*
	Research / evidence	No evidence of benefit; biomechanics of extrication; low rates of additional injury.	6 (18)	*the current research as well as provincial protocols shows that restricting patients on a [long spine board] has no benefit after the damage is done*
	Training / education	Training on proper technique; education for receiving facilities.	7 (21)	*more options for learning and not having fear of repercussions for decisions*
1.6 If your service's SMR could be improved, which patient groups, if any, would benefit from modified or special treatment? Option for "other" with free text				
26 (13)	Experience	Observed motion in treated patients over time; experiences with agitated patients; few actual injuries	19 (73)	**Bariatrics; *geriatrics; *wheelchair-dependent; *pre-existing conditions eg scoliosis; *sports collisions.*
	SMR causes motion	Collars uncomfortable; long backboard uncomfortable; patient movement worse when supine, when intoxicated, during transport.	7 (27)	*Bariatric/obese; those cannot tolerate laying supine*

	Adverse effects of treatment	Increased ICP; tissue damage	3 (12)	*It's very painful for geriatrics and causes further issues such as pressure sores*
1.9: If you feel there is a reason for a change in your practice over time, please explain: (short answer)				
90 (46)	Experience	Observed motion in treated patients over time; experiences with agitated patients; few actual injuries	74 (63)	*My experience has shown that immediately following SMR patient's can be cooperative but that quickly changes to agitated/uncomfortable and uncooperative. Causing more stress to the patient and their injuries (if any).*
	Explicit / formal workplace change	Protocol changes	37 (41)	*When the protocols changed for SMR, it was much more of a relief to not have a patient lying on a longboard for several hours on scene and at hospital causing lots of increased pain and discomfort.*
	Training / education	More training; higher certification level	14 (16)	*Also through my years I have gone from being a [BLS provider] to a licensed [ALS provider] so feel my assessment skills, knowledge and judgement have improved*
	Implicit / informal workplace changes	Changing culture of less punitive supervision; evolving standard of when it is necessary.	12 (13)	**Less fear in the workplace around disciplinary action towards not utilizing SMR.* **[Past practice] led to a vast number of unnecessarily boarded patients. Change in protocol and more leeway in critical decision making during assessment led to improvement in this area*
	Efforts to minimize movement	Deliberately undersize collar; do not change collar already place; forgo treatment; estimate/guess size	50 (79)	*Very rarely does the measurement provide any correlation with patients actual size. Hair/clothing, jaw size, weight all play into the comfort level of a patient in a cervical collar, If you place a collar on that is to small it will provide more comfort to the patient and allow for you to leave [it] in place to prevent you from having to take it out adjust and repeatedly causing more movement of a patient with a suspected spinal injury.*
2.6: If you do not very frequently/always measure [neck size for a cervical collar], which explanation best explains why (other free-text)?				
63 (32)	Efforts to minimize movement	Deliberately undersize collar; do not change collar already place; forgo treatment; estimate/guess size	10 (16)	*I estimate as close as possible as I prepare the collar for the patient as there is often limited space around patient.*
	Research / evidence	No evidence of benefit; biomechanics of extrication; low rates of additional injury.	9 (14)	*In my own research I have not been able to find any benefit to the treatment at all let alone to measuring.*

3.4: In which cases would you opt to use spinal precautions when they are not indicated by protocol (other free text)?

8 (4)	N/A	Indications actually present.	4 (50)	*Alcohol or drug intoxication; unconscious/responsive*
	Experience	Observed motion in treated patients over time; experiences with agitated patients; few actual injuries	2 (25)	*Other lower spinal injuries, and using clinical judgment*
	Experience	Observed motion in treated patients over time; experiences with agitated patients; few actual injuries	2 (25)	*Use to stabilize head movement in an intubated patient.*

3.6: In which cases would you opt NOT to use spinal precautions when indicated by protocol, other than refusal (other free text)?

17 (9)	SMR causes motion	Collars uncomfortable; long backboard uncomfortable; patient movement worse when supine, when intoxicated, during transport.	15 (88)	**Agitated patient that is fighting SMR/ moving more than if there were less SMR* **Geriatrics with kyphosis make a good example where c-collars are difficult to apply and I would use alternative immobilization techniques (such as towel rolls)*
	Efforts to minimize movement	Deliberately undersize collar; do not change collar already place; forgo treatment; estimate/guess size	2 (11)	*Some criteria met by protocol for SMR, but mild in severity (ie. Trauma in >65 but head trauma is minor, or distracting painful injury is not severe, with no midline neck pain) knowing that spine board will be very uncomfortable for patient and will cause suffering.*
	N/A	Refusal	2 (11)	*If it means that they will accept further care instead of a AMA [against medical advice] or refusal*

1. Not exclusive. Each response can contain multiple categories
2. Multiple quotations separated by an asterix (*)

SMR: Spinal Motion Restriction; ICP: intracranial pressure; MOI: mechanism of injury

Question 4.13 also had a free-text option but received no responses

Appendix 3.1, "Search strategies"

MEDLINE

1 emergency medical services.sh.
2 Emergency Medical Technicians/st, sn [Standards, Statistics & Numerical Data]
3 Ambulances/st, sn [Standards, Statistics & Numerical Data]
4 paramed$.tw.
5 prehospital.tw.
6 pre-hospital.tw.
7 ambulance.tw.
8 ems.tw.
9 emt.tw.
10 "first respond$".tw.
11 "emergency medical technician$".tw.
12 "emergency services".tw.
13 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12
14 Quality Improvement/st, sn, td [Standards, Statistics & Numerical Data, Trends]
15 Quality Assurance, Health Care/mt, st, sn, td [Methods, Standards, Statistics & Numerical Data, Trends]
16 "Information Storage and Retrieval"/mt, st, sn, td [Methods, Standards, Statistics & Numerical Data, Trends]
17 Data Collection/
18 Medical Records/
19 Electronic Health Records/
20 Health Records, Personal/
21 Medical Record Linkage/
22 Medical Records Systems, Computerized/
23 Registries/mt, og, st, sn [Methods, Organization & Administration, Standards, Statistics & Numerical Data]
24 (data$ adj3 (quality, or link$ or accu$ or digit$ or electronic$ or record or paramed$ or prehospital or pre-hospital)).tw.
25 "electronic medical record".tw.
26 "record linkage".tw.
27 "paramedic record".tw.
28 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27
29 13 and 28
30 limit 29 to yr="2011 -Current"

EMBASE

1	emergency health service/
2	rescue personnel/
3	ambulance transportation/
4	ambulance/
5	paramed$.tw.
6	prehospital.tw.
7	pre-hospital.tw.
8	ambulance.tw.
9	ems.tw.
10	"first respond$".tw.
11	"emergency medical technician$".tw.
12	"emergency services".tw.
13	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12
14	total quality management/
15	*clinical effectiveness/ or *performance measurement system/ or *program evaluation/ or *public health systems research/
16	information retrieval/
17	information storage/
18	data extraction/
19	medical information system/
20	electronic medical record/ or electronic medical record system/
21	*electronic health record/ or *electronic patient record/
22	*patient registry/ or *clinical trial registry/ or *death registry/ or *disease registry/
23	(data$ adj3 (quality, or link$ or accu$ or digit$ or electronic$ or record or paramed$ or prehospital or pre-hospital)).tw.
24	"electronic medical record".tw.
25	"record linkage".tw.
26	"paramedic record".tw.
27	14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28	13 and 27
29	limit 28 to yr="2011 -Current"

Scopus

1	KEY "emergency medical services"
2	KEY "emergency medical technicians"
3	KEY "ambulance"
4	KEY paramedic
5	KEY prehospital
6	KEY pre-hospital
7	KEY "first respond*"
8	KEY "emergency services"
9	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9
10	KEY "quality improvement"
11	KEY “quality assurance, health care"
12	KEY "information storage"
13	KEY "information retrieval"
14	KEY "data collection"
15	KEY "medical records"
16	KEY "electronic health records"
17	KEY "health records, personal"
18	KEY "medical record linkage"
19	KEY "medical records systems, computerized"
20	KEY "patient regist*"
21	TITLE-ABS-KEY data* W/3 ("quality" OR "link*" OR "accu*" OR "digit*" OR "electronic*" OR "record" OR "paramedic" OR "prehospital" OR "pre-hospital")
22	TITLE-ABS-KEY "electronic medical record"
23	TITLE-ABS-KEY "record linkage"
24	TITLE-ABS-KEY "paramedic record"
25	10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 O 19 OR 20 OR 21 OR 22 OR 23 OR 24
26	9 AND 25
27	LIMIT 26 (2011 - CURRENT)

CINAHL

1	(MH "Emergency Medical Services")	Expanders - Apply equivalent subjects
2	(MH "Emergency Medical Technicians")	Expanders - Apply equivalent subjects
3	(MH "Ambulances")	Expanders - Apply equivalent subjects
4	TX paramedic	Expanders - Apply equivalent subjects
5	TX prehospital	Expanders - Apply equivalent subjects
6	TX pre-hospital	Expanders - Apply equivalent subjects
7	TX ambulance	Expanders - Apply equivalent subjects
8	TX ems	Expanders - Apply equivalent subjects
9	TX emt	Expanders - Apply equivalent subjects
10	TX "first respond#"	Expanders - Apply equivalent subjects
11	TX "emergency medical technician#"	Expanders - Apply equivalent subjects
12	TX "emergency services"	Expanders - Apply equivalent subjects
13	**S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12**	**Expanders - Apply equivalent subjects**
14	(MH "Quality Improvement/TD/SN/ST")	Expanders - Apply equivalent subjects
15	(MH "Quality of Health Care/TD/SN/ST/MT")	Expanders - Apply equivalent subjects
16	(MH "Information Retrieval/MT/ST/TD/EV")	Expanders - Apply equivalent subjects
17	(MH "Information Storage/EV/MT/ST/TD")	Expanders - Apply equivalent subjects
18	(MH "Data Collection")	Expanders - Apply equivalent subjects
19	(MH "Medical Records")	Expanders - Apply equivalent subjects
20	(MH "Electronic Health Records")	Expanders - Apply equivalent subjects
21	(MH "Medical Records, Personal")	Expanders - Apply equivalent subjects
22	(MH "Medical Record Linkage")	Expanders - Apply equivalent subjects
23	(MH "Registry Personnel/MT/ST/SN/TD")	Expanders - Apply equivalent subjects
24	TX data# N3 (quality or link# or accu# or digit# or electronic# or record or paramedic or prehospital or pre-hospital)	Expanders - Apply equivalent subjects
25	TX "electronic medical record"	Expanders - Apply equivalent subjects
26	TX "record linkage"	Expanders - Apply equivalent subjects
27	TX "paramedic record"	Expanders - Apply equivalent subjects
28	**S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27**	**Expanders - Apply equivalent subjects**
29	**S13 AND S28**	**Limiters - Published Date: 20110101-20211231**

Appendix 3.2, "Data-extraction form"

	RANGE				EXTENT			NATURE				
Study	**Location**	**Year**	**Purpose**	**Clinical area**	**Level of Data Being Assessed**	**Breadth of Data Being Assessed**	**Duration of Data Being Assessed**	**Prehospital Data Field Assessed**	**Method of Assessment**	**Result of Assessment**	**Domain - as identified by study, if done**	**CIHI Domain, if applicable**
Study citation	*Geographic location of data being assessed*	*Of publication*	*As stated by study*	*If applicable*	*Refers to jurisdictional level, whether individual service, state / province, national, international*	*Refers to spread of data being assessed at whichever level: for example, data from one service linked to multiple state / provincial databases*	*Time frame of included data*	*Variables assessed. If possible, these will be summarized by general categories, such as: Patient demographics, call characteristics, subjective information, interventions, vital signs, etc.*	*Can include overall research method, experimental design, and specific assessment techniques*	*As reported, potentially summarized by category*		

Appendix 4.1, "List all of all included studies"

Abir M, Taymour RK, Goldstick JE, et al. Data missingness in the Michigan NEMSIS (MI-EMSIS) dataset: a mixed-methods study. *Int J Emerg Med*. 2021;14(1):22. doi:https://dx.doi.org/10.1186/s12245-021-00343-y

Alstrup K, Petersen JAK, Barfod C, Knudsen L, Rognås L, Møller TP. The Danish helicopter emergency medical service database: high quality data with great potential. *Scand J Trauma Resusc Emerg Med*. Apr 5 2019;27(1):38. doi:10.1186/s13049-019-0615-5

Andrews R, Wynn MT, Ter Hofstede AHM, et al. Leveraging data quality to better prepare for process mining: An approach illustrated through analysing road trauma pre-hospital retrieval and transport processes in Queensland. *Int J Environ Res Public Health*. 2019;16(7):1138. doi:http://dx.doi.org/10.3390/ijerph16071138

Andrusiek DL, Hall CA, Votova KM, Randhawa GK. Use of force in police-public encounters and medical outcomes: Issues with linking police and emergency medical services (EMS) data. *CJEM*. 2012;14(SUPPL. 1):S49. 2012 CAEP/ACMU Scientific Abstracts. Niagara Falls, ON Canada.

Asimos AW, Ward S, Brice JH, et al. A geographic information system analysis of the impact of a statewide acute stroke emergency medical services routing protocol on community hospital bypass. *J Stroke Cerebrovasc Dis*. 2014;23(10):2800-2808. doi:http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2014.07.004

Babcock L, Lloyd J, Semenova O, Meinzen-Derr J, Depinet H. Prehospital capture of variables commonly used in ED sepsis screening tools. *Pediatrics*. 2019;144(2)National Conference on Education 2018. Orlando, FL United States. doi:http://dx.doi.org/10.1542/peds.144.2-MeetingAbstract.412

Barley CR, Gunson IM. Rates of recording different aspects of patients' social history on ambulance electronic patient records-a service evaluation. *Emerg Med J*. 2021;38(9)999 EMS Research Forum 2021 Conference. Online. doi:http://dx.doi.org/10.1136/emermed-2021-999.38

Berben SAA, Scholten AC, Westmaas AH, et al. Pain management in trauma patients in (pre)hospital based emergency care: Current practice versus new guideline. *Injury*. 2015;46(5):798-806. doi:http://dx.doi.org/10.1016/j.injury.2014.10.045

Bergrath S, Skorning M, RÃ¶rtgen D, et al. Is paper-based documentation in an emergency medical service adequate for retrospective scientific analysis? An evaluation of a physician-run service. *Emerg Med J*. 2011;28(4):320-324. doi:10.1136/emj.2009.086538

Bessant G, Dharmaratne S. Annual tourniquet use in UK ambulance services for major haemorrhage control. *BMJ Open*. 2017;7(Supplement 3):A5. 2nd European Emergency Medical Services Congress, EMS 2017. Copenhagen Denmark. doi:http://dx.doi.org/10.1136/bmjopen-2017-EMSabstracts.13

Betlehem J, Deutsch K, Marton J, et al. The importance of accurate examination of stroke patients in prehospital emergency care. *Cerebrovascular Diseases*. 2013;35(SUPPL. 3):478. 22nd European Stroke Conference. London United Kingdom.doi:http://dx.doi.org/10.1159/000353129

Blanchard IE, Williamson TS, Ronksley P, et al. Linkage of Emergency Medical Services and Hospital Data: A Necessary Precursor to Improve Understanding of Outcomes of Prehospital Care. *Prehosp Emerg Care*. Oct 20 2021:1-10. doi:10.1080/10903127.2021.1977438

Bloomer R, Burns BJ, Ware S. Improving documentation in prehospital rapid sequence intubation: investigating the use of a dedicated airway registry form. *Emerg Med J*. 2013;30(4):324-6. doi:https://dx.doi.org/10.1136/emermed-2011-200715

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