Review Article

Impact of telemedicine on diagnosis, clinical management and outcomes in rural trauma patients: A rapid review

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Abstract

Introduction: Rural trauma patients are at increased risk of morbidity and mortality compared to trauma patients treated in urban facilities. Factors contributing to this disparity include differences in resource availability and increased time to definitive treatment for rural patients. Telemedicine can improve the early management of these patients by enabling rural providers to consult with trauma specialists at urban centres. The purpose of this study was to assess the impact of telemedicine utilisation on the diagnosis, clinical management and outcomes of rural trauma patients.

Materials and Methods: A rapid review of the literature was performed using the concepts 'trauma', 'rural' and 'telemedicine'. Fifteen electronic databases were searched from inception to 29th June 2018. Manual searches were also conducted in relevant systematic reviews, key journals and bibliographies of included studies.

Results: The literature search identified 187 articles, of which 8 articles were included in the review. All 8 studies reported on clinical management, while the impact of telemedicine use on diagnosis and outcomes was reported in 4 and 5 studies, respectively. Study findings suggest that the use of telemedicine may improve patient diagnosis, streamline the process of transferring patients and reduce length of stay. Use of telemedicine had minimal impact on mortality and complications in rural trauma patients.

Conclusions: The evidence identified by this rapid review suggests that telemedicine may improve the diagnosis, management and outcomes of rural trauma patients. Further research is required to validate these findings by performing large and well-designed studies in rural areas, ideally as randomised clinical trials.

Keywords: Rapid review, rural, telemedicine, trauma

Résumé

Introduction: Les traumatisés en région rurale présentent un risque accru de morbidité et de mortalité comparativement aux traumatisés des établissements en région urbaine. Les facteurs qui contribuent à cette disparité sont les différences quant à la disponibilité des ressources et un délai prolongé avant d'accéder au traitement définitif chez les patients des régions rurales. La télémédecine améliore la prise en charge précoce de ces patients en permettant aux fournisseurs en milieu

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rural de consulter des spécialistes en traumatologie des centres urbains. Cette étude avait pour but d'évaluer l'impact de la télémédecine sur le diagnostic, la prise en charge clinique et les résultats chez les patients traumatisés en milieu rural.

Méthodologie: Un examen rapide de la littérature a été effectué à l'aide des mots-clés anglais « trauma », « rural » et « telemedicine ». La recherche a eu lieu dans 15 banques de données électroniques à compter de leur lancement jusqu'au 29 juin 2018. Des recherches manuelles ont également été effectuées dans les revues systématiques et publications scientifiques pertinentes et dans les bibliographies des études incluses.

Résultats: La recherche de la littérature a donné lieu à 187 articles, dont 8 ont été inclus dans la revue. Les 8 études portaient sur la prise en charge clinique, alors que l'impact de la télémédecine sur le diagnostic et les résultats a fait l'objet de 4 et de 5 études, respectivement. Les résultats des études laissent croire que la télémédecine améliorerait le diagnostic, simplifierait le processus de transfert des patients et raccourcirait le séjour. La télémédecine a eu un effet minime sur la mortalité et les complications chez les patients traumatisés en milieu rural.

Conclusions: Les données probantes relevées par cet examen rapide laissent croire que la télémédecine améliorerait le diagnostic, la prise en charge et les résultats chez les patients traumatisés en milieu rural. D'autres recherches sont nécessaires pour valider ces conclusions par l'entremise d'études d'envergure bien conçues menées en régions rurales, idéalement sous forme d'études cliniques à répartition aléatoire.

Mots-clés: rural, télémédecine, patients traumatisés en milieu rural, diagnostic des patients en milieu rural

INTRODUCTION

Trauma patients have better outcomes when they receive treatment at a major trauma centre in a timely manner.[1] Compared to patients injured in urban areas, rural trauma patients are less likely to be treated at a trauma centre and twice as likely to die before they reach hospital.[2] Potential reasons why rural trauma patients do not reach hospital or are treated outside a major trauma centre include delays in alerting or transport by emergency medical services, distance from the injury location or rural facility to the nearest trauma centre, high thresholds for rural providers to transfer patients and patient preference to remain close to their family and community.[2] Furthermore, rural facilities tend to have limited resources, including access to trauma specialists[3] and technical equipment,[4] which can lead to delays in diagnosis and definitive treatment, as well as increased interfacility transfers to specialised trauma centres.[5]

Delays to definitive treatment have a negative impact on survival and long-term morbidity following a traumatic event.[1] In light of the concepts of the 'golden hour' and 'platinum 10 min', improved patient outcomes following severe traumatic injury are possible with timely diagnosis and treatment.[6,7] Telemedicine offers a solution to the challenges of rural trauma care by connecting providers on the scene and at rural hospitals with experts at trauma centres for real-time advice on the management of trauma patients.[8-12] Since the turn of the 21st century, there has been a gradual proliferation of telemedicine applications for interactive, multimedia communication during various phases of trauma care, including pre-hospital (field evaluation and transport), in-hospital (emergency department [ED], inpatient, intensive care unit [ICU]) and follow-up/rehabilitation.[13-16] When properly implemented, telemedicine has the potential to significantly improve rural trauma care by increasing access, decreasing costs and enhancing quality in areas of need.[15] Although previous systematic reviews (SRs) have examined the use of telemedicine to treat and manage various patient populations,[17-20] none have focused specifically on the trauma population treated in rural areas.

The research question that guided this review was as follows: What is the impact of telemedicine utilisation on the diagnosis, clinical management and health-related outcomes of rural trauma patients?

MATERIALS AND METHODS

A rapid review was conducted to synthesise evidence regarding the impact of telemedicine on the diagnosis, management and health-related outcomes

of rural trauma patients. Rapid reviews are 'a form of knowledge synthesis in which components of the SR process are simplified or omitted to produce information in a timely manner.'[21] Rapid reviews follow all the steps of a state-of-the-art SR but truncate some of them to save time.[22]

This rapid review followed the PRISMA guidelines and truncated on the grey literature search, quality assessment of included studies and double screening and data extraction (details are presented in the sections *Search criteria* and *Review process and data extraction*). The Participants, Intervention, Comparison, Outcome (PICO) that guided this review was as follows: (P) trauma patients, (I) treated with telemedicine in rural area, (C) any comparison and (O) diagnosis, management and patients' health.

Search criteria

A search of the literature was conducted in September 2017 and updated in June 2018. The search strategy involved keywords specific for the following three concepts: (1) rural areas; (2) telemedicine and (3) trauma [Table 1]. No limits were placed on study location, publication date or language. A total of 15 electronic databases were searched; the search was launched on title and abstract. In addition, one reviewer hand-searched the bibliographies of all included studies, nine literature reviews on telemedicine in rural trauma[19,23-30] and all issues of two relevant journals (Journal of Telemedicine and Telecare; Telemedicine and e-Health) that were published between 2010 and 2017. The hand search was performed by looking for a combination of keywords ([telemedicine AND rural] OR [telemedicine AND trauma]) in the title of each article; if found, the inclusion criteria were applied to the study abstract and full text. The references of any relevant articles identified via manual searching were also searched using the same approach.

Review process and data extraction

Two independent reviewers screened the search results by title and abstract using the reference management software Zotero. Original articles and abstracts published in peer-reviewed journals were eligible for inclusion. The inclusion criteria were as follows: (1) empirical study; (2) experimental, before and after, interrupted time series, cohort or comparative research design; (3) use of telemedicine as an intervention in trauma patients; (4) reporting on diagnosis, clinical management or health-related outcomes and (5) rural hospital setting (as there is no widely accepted definition of rurality,[31] the articles were included if the author defined the setting as being rural). Articles included in the initial screening process underwent secondary screening of the full text by one reviewer. Articles that contain any level of uncertainty were validated by a second reviewer.

A standardised data extraction form was designed in Microsoft Word and used by a single reviewer to collect the following information: study location, design, publication date, sample size, study population, injury types and type of telemedicine technology. Information reported on patient diagnosis or clinical management, as well as patient outcomes for mortality, complication rates,

Table 1: Search strategy (Launched September 2017 and June 2018)

Concepts	Keywords
Rural	Rural* OR remote* OR isolat* OR insulat* OR island* OR reserve* OR countryside* OR 'non-metropolitain*' OR suburban*
	AND
Telemedicine	Telemedicine* OR telehealth* OR telemonitoring OR ehealth* OR 'information technolog*' OR teletrauma*
	AND
Trauma	Trauma*
Consulted databases	
Academic Search Premier	
Arctic and Antarctic Regions	
CINAHL Plus with Full Text	
CINAHL	
Communication and Mass Media Complete	
Communication Abstracts	
Computers and Applied Sciences Complete	
Ergonomics abstracts	
Human resources abstracts	
Library Literature and Information Science Full Text (H.W. Wilson)	
Library, Information Science and Technology Abstracts	
MEDLINE	
PubMed	
Social Sciences Full Text (H.W. Wilson)	
SPORTDiscus with Full Text	

length of stay (LOS) and interhospital transfers was collected. If there was any uncertainty during data extraction, a second reviewer was consulted to discuss the issue. Simple descriptive statistics were used to report the results.

RESULTS

Study characteristics

The literature search yielded a total of 187 results, of which 8 articles met the inclusion criteria [Figure 1].

Characteristics of the included studies are shown in Tables 1 and 2. Most studies (n = 7) were conducted in the United States;[3,13,18,32-35] the remaining study was performed in China.[17] Three studies were published before 2010, and 5 studies were published during or after 2010. Studies varied considerably in sample size and population. In each study, data were collected on trauma patients at multiple rural facilities, ranging from as few as 4 rural facilities[13] to as many as 249 rural hospitals.[17] In 6 articles, the study population included all types of trauma patients;[3,13,17,32,33,35] the remaining 2 articles were limited to patients with head trauma[34] or burns.[18]

The predominant telemedicine technology used was a real-time audio–video connection between the referring rural hospital and the receiving facility (n = 6). Three articles also reported asynchronous transmission of digital images or videos that could be stored and reviewed by physicians at the receiving facility. Three types of methodological approaches were used to test the impact of telemedicine on the evaluation, management and outcomes of rural trauma patients. The most prevalent method was to compare outcomes between patients treated with or without the support of telemedicine (n = 5). Two studies examined variations in diagnoses and decisions regarding patient management before and after use of telemedicine by physicians, and the remaining study compared video-enhanced telemedicine with telephone alone.[18] Among studies that compared patient outcomes, with or without the use of telemedicine, patients in the telemedicine group tended to be more severely injured.

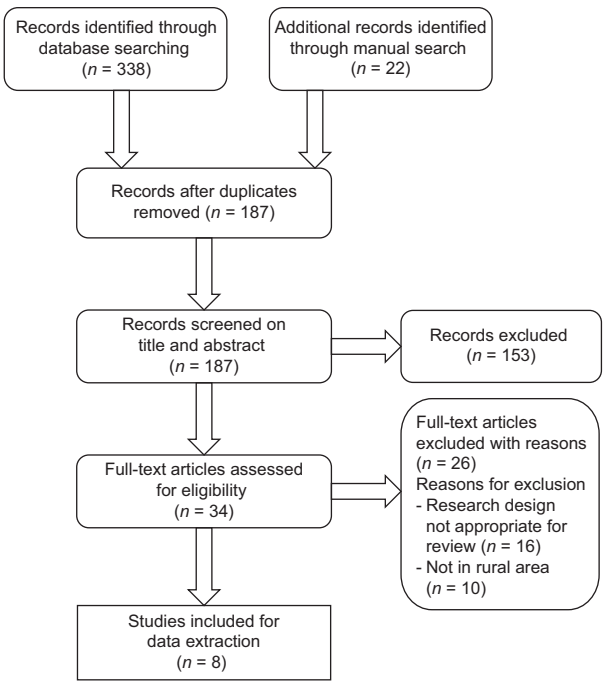

Figure 1: Flow diagram.

Diagnosis

Wang *et al.* examined rural injuries involving a telemedicine consult and found that this led to a change in diagnosis for 29.3% of patients and a change in treatment for 61.4% of patients. In 66.5% of cases involving treatment changes following a telemedicine consult, the change was not due to a change in diagnosis, leading the authors to suggest that even when the primary care physician made the correct diagnosis, the prescribed therapy was often inappropriate.[17] Following implementation of telemedicine, Duchesne *et al.* reported improved radiological evaluation and earlier identification of severely injured patients.[3] Mohr *et al.* observed no difference in the ordering or use of computed tomography (CT) scans and chest X-rays at the first ED with telemedicine use;[33] however, in the hospitals where telemedicine was available, there was an increased use of CT scans (adjusted odds ratio [aOR] 1.6, 95% confidence interval [CI] 1.3–1.9) and X-rays (aOR 1.3, 95% CI 1.1–1.5). In a second study, Mohr *et al.* found that moderately injured patients (injury severity score (ISS) 4–8) were more likely to receive a telemedicine consultation (aOR 1.45, 95% CI 1.05–2.01).[32]

Clinical management

All 8 studies in this review reported on patient transfers [Table 2]. Two studies observed

Table 2: Summary reporting table

Reference	Country (city)	Date	Injuries	Design	Sample size	Telemedicine system	Results
Doheny-Farina (2003)[13]	USA (Vermont and New York)	April 5, 2000-June 29, 2001	Different trauma injuries	Comparison of outcomes between patients treated with and without telemedicine	19 patients treated with telemedicine 266 patients not treated with telemedicine	Interactive video telemedicine system	No impact on complications No impact on LOS No greater mortality rate
Duchesne (2008)[3]	USA (Mississippi)	January 2000-January of 2005	Different trauma injuries	Retrospective comparison of patients' outcomes before and after the implementation of telemedicine	351 patients before implementation of telemedicine 51 patients after implementation of telemedicine	Dual video cameras with remote control capability and audio	Improvement of evaluation and management of trauma patients More severely injured trauma patients were identified No impact on mortality Decreased LOS Decreased transfer time
Mohr (2017)[32]	USA (North Dakota)	2008-2014	Different trauma injuries	Comparison of outcome between patients treated with and without telemedicine	2536 patients not treated with telemedicine 301 patients treated with telemedicine	Two-way high-definition audio-video connection	Tele-trauma consultations were requested for the most severely injured patients No impact on interhospital transfers
Mohr (2018)[33]	USA (North Dakota)	2008-2014	Different trauma injuries	Comparison of outcome between patients treated with and without telemedicine	4838 patients where telemedicine was unavailable 2662 patients where telemedicine was available 2371 patients not treated with telemedicine when it was available 291 patients treated with telemedicine	Two-way high-definition audio-video connection	Decreased LOS for transferred patients Increased CT use Increased X-ray use No impact on mortality rate

Contd...

Table 2: Contd...

Reference	Country (city)	Date	Injuries	Design	Sample size	Telemedicine system	Results
Moya (2010)[34]	USA (New Mexico)	November 2007-October 2008	Head trauma	Changes of decision by the consulting physician concerning the patient transfer and management before and after reviewing the digital images.	39 patients	Transmission of digital Brain and spine images	Decreased in transfer Recommended management changes
Ricci (2003)[35]	USA (Vermont and New York)	April 2000-November 2002	Different trauma injuries	Comparison of outcome between patients treated with and without telemedicine	41 patients treated with telemedicine 762 patients not treated with telemedicine	Audio-video connection	No impact on time between injury and arrival at referral trauma centre No impact on LOS Slightly more complications Increased mortality rate Patients treated with telemedicine had higher ISS
Wang (2016)[17]	China (Western regions of China)	May 2002-December 2013	Different trauma injuries	Diagnosis and treatment changes before and after the teleconsultation	11,987 patients	Two-way video and image Transmission	Increased chances of major diagnostic change Increased chances of treatment change Most treatment changes were not due to diagnostic change
Wibbenmeyer (2016)[18]	USA (Iowa)	January 2012-January 2014	Burn patients	Comparison of outcome between patients treated with and without telemedicine	204 patients treated with telephone only 78 patients treated with telemedicine	Transmission of videos of patients' injuries	Greater accuracy to correctly classify burn size More accurate initial resuscitation and triage decisions More changes in admission

ISS: Injury severity score, LOS: Length of stay.

a reduction in transfer time with use of telemedicine. Duchesne *et al.* found that telemedicine helped physicians to quickly identify and transfer severely injured patients, which resulted in decreased transfer time (1.7 h vs. 13 h, $P < 0.001$).[3] Mohr *et al.* reported that telemedicine use was associated with earlier arrival at the final hospital (mean difference 33.6 min, 95% CI 15.2–52.1 min).[33] In 2 other studies, there was no difference in transfer time between patients treated with or without telemedicine.[13,35] In their study comparing the use of video-enhanced telemedicine versus telephone telemedicine in burn patients, Wibbenmeyer *et al.* found no difference in the proportion of patients transferred by air, ground or private transport.[18] The authors reported that compared with telephone alone, use of video-enhanced telemedicine decreased over- or under-resuscitation and increased triage changes in transport mode.[18] Video-enhanced telemedicine also improved the ability of charge nurses to estimate burn size, but this difference was not significant.

The likelihood of patient transfer was examined in 2 studies by Mohr *et al.*;[32,33] in both studies, telemedicine use was not associated with interhospital transfer after adjusting for confounding variables. There were 2 studies that examined the proportion of rural trauma patients transferred after a telemedicine consultation was performed. Wang *et al.* observed that 2.8% of injured patients were transferred after a telemedicine consult.[17] Moya *et al.* reported that consulting neurosurgeons initially believed 64% (25/39) of referral requests required transfer; however, only 36% (14/39) of these patients were actually transferred after the neurosurgeons performed a review of web-based images.[34] Finally, Moya *et al.* observed that use of telemedicine resulted in recommendations for management changes in 44% (17/39) of cases treated in rural EDs.[34]

Outcomes

Table 2 shows the impact of telemedicine use on outcomes among rural trauma patients. There were 4 studies which reported on mortality; in 3 of these studies, there was no difference in mortality with the use of telemedicine.[3,13,33] In the remaining study, Ricci *et al.* observed a higher mortality rate in patients treated using telemedicine (25% vs. 9%, $P = 0.003$).[35] However, after controlling for injury severity, the difference in mortality was rendered insignificant (8.8% vs. 5.7%, $P = 0.41$). Only 2 studies reported on complications;[13,35] neither study found a difference in complications with the use of telemedicine.

In 4 studies, the authors evaluated the impact of telemedicine on LOS in rural trauma patients. Two of these studies found that LOS was decreased with use of telemedicine. Duchesne *et al.* reported that on average, the LOS at the local community hospital of patients treated with telemedicine was 1.5 h versus 47 h for those treated without this technology ($P = 0.001$).[3] Mohr *et al.* found that compared to patients treated without telemedicine, ED LOS for transferred telemedicine patients decreased by 29.6 min (95% CI 14.1–45.1 min) but was not decreased among non-transferred telemedicine patients (mean difference 9.3 min, 95% CI 11.7–30.2). The telemedicine network in this study by Mohr *et al.* used a hub-and-spoke architecture which connected rural providers to a board-certified ED physician and nurse 24 h a day. The authors suggested that the decreased ED LOS they observed among transferred patients likely reflected the ability of the telemedicine hub staff to mobilise transportation resources faster than local providers, even while bedside providers performed the initial evaluation and resuscitation.[33] The other 2 studies did not observe a difference in LOS at the referral trauma centre with the use of telemedicine.[13,35]

DISCUSSION

As the reality of rural and urban healthcare facilities differ in many ways,[2-5] scientific evidence should, when deemed relevant, acknowledge these distinctions and provide information that relates distinctively to rural or urban healthcare centres. Numerous studies have investigated the use of telemedicine in a variety of environments and patient populations, yet evidence on telemedicine utilisation in rural trauma care specifically is still lacking. This rapid review is the first study to systematically examine the impact of telemedicine on the diagnosis, management and outcomes in trauma care treated in rural areas. Our results demonstrate that use of telemedicine had minimal impact on patient mortality, but it improved patient

evaluation and diagnosis, decreased transfer time and reduced LOS in some studies. These findings suggest that the use of telemedicine can improve certain types of care provided to rural trauma patients.

Telemedicine platforms link rural providers with specialised trauma centres to better evaluate and manage trauma patients.[34] This is especially important for seriously injured patients who can be challenging to evaluate due to lower levels of consciousness and the complex nature of traumatic injuries.[36,37] Previous research has demonstrated that it is feasible for surgeons at a tertiary centre to view and guide trauma resuscitations in rural facilities using real-time tele-ultrasound.[14] Several of the studies included in this review reported that trauma patients who were treated with telemedicine had higher injury severity score (ISS) scores.[3,13,32,33] This may be explained by the fact that rural physicians are more likely to seek help in cases involving severely injured patients, where rapid management is critical and potentially lifesaving. It has been shown that diagnostic or management errors happen more frequently during the initial steps of resuscitation.[38] These errors can have serious consequences for the patient such as additional surgical procedures, permanent disability or even death.[37,39]

Interestingly, a number of studies in this review showed that use of telemedicine can improve the process of transferring rural trauma patients.[3,33,34] It is known that for similar patients, rural facilities are more likely than urban centres to transfer trauma patients, especially those with head or neck injuries.[40] Having access to specialists at a tertiary facility can enable faster triage and patient transfer[41,42] and better prepare providers at the trauma centre to receive the patient.[34] Although transferring a patient may be necessary, it is often a stressful, unpleasant and even scary transition for the patient, who is in a vulnerable state.[43] Delays in transfer can contribute to poor patient outcomes. Experienced physicians rarely accompany the transferred patient during transport; if a physician does travel with their patient, it takes away a key resource from the rural facility.[44] Importantly, telemedicine can help to reduce the number of transfers by enabling trauma patients to be treated in rural hospitals.[34] Keeping manageable patients in the rural ED can positively impact resource use by reducing unnecessary transports and admissions to an urban trauma centre. Further study is warranted to evaluate the use of telemedicine to minimise unnecessary transfers among rural trauma patients.

An earlier systematic review of telemedicine applications found that most studies were focused on diagnosis, while relatively few assessed clinical management or patient outcomes.[45] By comparison, the 8 articles identified in our review of telemedicine utilisation in rural trauma were predominantly focused on clinical management. Patient outcomes were reported in 5 articles, and the findings of these studies suggest that telemedicine may reduce LOS in rural trauma patients but has minimal effect on mortality or complications. Although patients who had telemedicine consults did receive specialised care from providers at a trauma centre, they also tended to be more severely injured; the balance of these two factors may partly explain the observed minimal effect of telemedicine on complication and mortality. There is evidence that telemedicine can reduce mortality when applied to other settings, including prehospital diagnosis of ST elevation myocardial infarction,[46] the ICU,[47] and progressive care units.[48]

In addition to improving patient outcomes, the application of telemedicine also has great potential to enhance the education of providers at rural facilities.[49] Telemedicine offers a solution that addresses disparities in access to trauma education by enabling them to connect, interact and learn from trauma specialists. Future directions of telemedicine initiatives involve broader use of these technologies in the prehospital setting and providing informatics that allow trauma specialists to respond to consultation requests anywhere where they have a smartphone with internet reception.[50]

This study has some limitations. Our search strategy identified a small number of studies which varied considerably in research design, telemedicine systems and measures related to care of the rural trauma patient. Moreover, there was variation in rural settings and institution-based application of telemedicine to rural trauma care, further limiting the generalisability of our findings. Finally, as this was a rapid review of the literature, we did not search for grey literature or appraise study quality of included articles.

Due to the fact that it was a rapid review, some steps were truncated. In their study that compared rapid reviews and SRs, Reynen *et al.* found that even if there exist differences in terms of quality and exhaustivity, the conclusions drawn from the rapid reviews were generally similar to those of the full SRs.[51] Rapid reviews were also found to be useful for decision-makers as they are used to inform the decision-making process.[21]

CONCLUSIONS

The findings of this rapid review suggest that the use of telemedicine can improve the diagnosis, management and outcomes of rural trauma patients. While these results are promising, further research is required to validate these findings through the conduct of large-scale well-designed studies, ideally as randomised clinical trials.

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