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Telemedicine in Acute Trauma Care: A Review of Quantitative Evaluations on the Impact of Remote Consultation

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Abstract

Background: There is extensive literature describing the application of telemedicine techniques to trauma care. However, there is a paucity of articles showing quantitative assessment of its safety and efficacy. This structured review examines articles with quantitative assessment of telemedicine's impact in acute trauma care.

Methods: Medline and CINAHL databases were searched for peer-reviewed articles that quantitatively assess the impact of telemedicine on diagnostic accuracy, clinical decision-making, emergency department length of stay, transfer rates, and mortality in initial trauma management.

Results: Only 9 of the 408 screened articles met the criteria for quantitative assessment. Telemedicine appears to be preferentially used for more severely injured patients. Limited quality evidence supports procedural interventions at remote sites. Telemedicine may help abbreviate pre-transfer length of stay. However, its impact on diagnosis and mortality remains unclear.

Conclusions: Telemedicine's potential to enhance the quality and efficiency of trauma care, especially for resource-scarce areas, warrants continued quantitative research.

Keywords
trauma surgery, telemedicine, acute care surgery, remote consultation, diagnostic accuracy, injury severity assessment

Highlights

- Study examines telemedicine's utility in severe trauma cases.
- Telemedicine impacts trauma diagnosis, treatment, and transfers.
- Remote consultations aid in acute trauma decision-making.
- Improved methodological diligence is needed in telemedicine research.

Introduction

Trauma is considered a surgical subspecialty, frequently managed at high-level designated trauma centers, with trained trauma experts, and may require multiple subspecialty resources. A reduction in mortality has been reported among moderate to severely injured patients receiving care at designated level 1 trauma centers compared to non-trauma centers.[1] Numerous opportunities to compromise trauma resuscitations exist through the potential for errors of omission, commission, and misprioritization which can be life-threatening. Yet, severe injuries occur in a broad geographical distribution, with patients frequently presenting to outlying or rural hospitals for initial evaluation and stabilization. There, patients are frequently managed through the best efforts of clinicians with varying degrees of trauma training and experience including nurse practitioners, family physicians, or emergency medicine physicians. Secondary transfer of trauma patients from outlying hospitals to higher-level trauma centers occurs frequently and introduces additional risks and resource burdens.

There is a growing body of literature supporting the use of telemedicine (TM) to aid in the evaluation and management of acutely injured patients. Unfortunately, most of this literature exists as editorials, feasibility reports, or

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qualitative assessments of user satisfaction. Prior review articles examining the use of TM in trauma care have summarized findings across a broad range of emergency clinical scenarios,[2] a broad range of specialties participation,[3] or a broad scope in the phase of care.[4] All these cite problems with the methodological quality of available literature, and all include a broad range of methodologies and clinical scenarios. However, none of the prior reviews focuses on quantitative evidence in the context of acute primary trauma care.

Telemedicine encompasses a broad scope of techniques including store-and-forward style consultation, home monitoring with direct patient interaction, or interprofessional communication for specialty advice on patient care. Although telemedicine has been in practice for over six decades, its adoption surged during the recent COVID pandemic as it reduced travel burden and minimized interpersonal exposures.[5] Independent of pandemic considerations, the general utility of Telemedicine is to introduce specialty perspectives at an earlier point in the patient's care.

The modern era of Telemedicine began with remote physiologic monitoring, introduced for the Mercury Space Program in the late 1950s.[6] The application of video technology for civilian hospital medicine was introduced in the late 1950s and early 1960s when closed circuit TV was used for psychiatric consultations between the Norfolk State Hospital and the Nebraska Psychiatric Institute.[7] Interest in telemedicine grew rapidly in the context of disaster management[8] and battlefield medicine.[9] Stepwise improvements in technology led to the advancement of telemedicine applications in multiple specialties, where it has been primarily studied for feasibility and resource utilization.[10] Various telemedicine techniques have been used to support the fields of psychiatry,[11] neurology,[12] primary care,[13] radiology,[14] and emergency medicine.[15] Remote evaluation of trauma resuscitations began with the review of video recordings as a teaching tool as described by Hoyt in 1988[16] and later as a quality assurance tool in the early 1990s. This senior author described one of the earliest attempts to quantify the clinical accuracy of trauma evaluations by remote observation using an ATLS based protocol.[17]

Since its introduction, the use of telemedicine in trauma care has received relatively little attention, and little scientific scrutiny, even though trauma represents a field where TM could have significant potential benefits. A recent white paper from the American College of Surgeons states that telemedicine can be instrumental for rapid expert consultations in emergent situations, potentially guiding onsite staff in addressing the urgency of surgical interventions and may improve patient outcomes.[18] There are greater challenges in applying telemedicine techniques to acute trauma care relative to subspecialty care, due to a broader scope and lack of predetermined diagnoses. Proponents for telemedicine in acute trauma care point out its potential benefits. These benefits include the ability to improve diagnostic efficiency and reliability by guiding the proper utilization of diagnostic tests, without overutilization; the ability to influence therapeutic decisions, such as early airway control, chest tube placement, or management of bleeding; the ability to influence transfer decisions, so that transfer can be expedited when needed and avoided if there is little predictable benefit from the transfer. Additionally, theoretical arguments are made about how improved utilization of resources can lead to lower costs and reduce the burden on overstretched trauma centers. However, proponents of telemedicine seldom discuss the potential pitfalls. Remote evaluation of trauma patients may have limited reliability in interpreting history and physical exam findings compared to on site evaluation; may lead to frequent overdiagnosis or missed injury; may contribute to bad or damaging decisions for therapeutic interventions; may increase the cost of diagnosis through recommendations for unnecessary testing; and may promote unnecessary transfers or reject transfers of severely injured patients that would have benefited from specialized care. We believe that the resolution of these conflicting viewpoints will require well-structured quantitative studies.

This is a focused review of articles from peer-reviewed mainstream clinical literature that applies quantitative methods to remote clinical evaluation in the context of acute civilian trauma. The objective is to summarize the impact of telemedicine on mortality relative to Injury Severity Score (ISS), diagnostic accuracy, therapeutic decisions, transfer rates, and emergency department length of stay, thereby identifying gaps in current knowledge.

Methods

As a review article reporting only previously published data, the project is exempt from Institutional Review Board review under 45 CFR part 46. This review examines articles retrieved by a combination of electronic literature search and manual review of bibliographies from relevant articles and previously published reviews. The Medline[19] database of the National Library of Medicine and CINAHL[20-22] databases were chosen as the reference sources to identify articles in mainstream clinical literature subject to peer review. A combination of several reiterative string search and block search techniques were performed using the EBSCOhost search engine.[21] Efforts were made to optimize a balance of Recall and Precision as (Defined in Figure 1).[23] All searches were completed by March 31, 2023, without specifying a start date filter.

A string search was performed on the term "telemedicine or telehealth" as a major subject, which yielded a higher article count than either term alone. No additional articles were retrieved by the inclusion of "remote consultation." The terms "trauma" or "wounds and injuries" as major subjects yielded a higher article count than either term alone. The search parameters were set to include subheadings so that more specific terms would be automatically included in the results. These search results were combined with the conjunction "AND" to identify the intersection of article sets. This identified 542 articles. Once these were limited to English language articles and those published in scholarly, peer-reviewed journals, there were 473 articles for consideration. Articles without an abstract available and redundant citations were eliminated, leaving 408 articles for manual screening. The titles and abstracts of these 408 articles were manually reviewed by the authors to identify those that met our inclusion criteria of describing a quantitative evaluation of audio-video telemedicine techniques with or without adjunctive physiologic monitoring in the context of acute civilian trauma care. We intentionally excluded articles that used only qualitative methods to examine the impact of telemedicine in trauma.

The final screening eliminated articles under our exclusion criteria. These included a focus on teleradiology, psychological trauma, wound care, burns, single injuries such as hand, face, or fracture management, rehabilitation and follow-up, home care, editorials, feasibility articles, and those with only qualitative evaluation of user satisfaction. We intentionally excluded articles that focused on the utilization of asynchronous telemedicine, non-acute trauma, or any type of follow-up care.

Seventeen articles were selected for full-text review with 9 articles[24-32] representing the final set that describe remote evaluation of injured patients by a trauma specialist and quantified the impact of telemedicine on at least one of diagnostic accuracy, therapeutic decisions, emergency department length of stay, or transfer rates. The search terms, search component results, and article selection process are shown in Figure 1. The references of selected articles and 3 previous reviews[3,4] was examined without identifying any articles missed by the search. The distribution of the outcome measures described in each article was tabulated and the major findings of each article are presented.

Results

The initial subject-based search of Medline and CINAHL yielded many feasibility, editorials, and qualitative articles that support telemedicine as a process of care to evaluate and manage injured patients. However, few articles apply any degree of quantitative rigor to assess the diagnostic accuracy, impact on treatment, effects on transfer rates, emergency department length of stay, or mortality. After 408 articles passed electronic screening, manual screening identified only 9 articles of primary interest, describing quantitative assessments of telemedicine effectiveness in acute trauma. This indicates the search has a very low precision metric of 0.02 (9/408), defined as the proportion of relevant articles to total articles retrieved. The precision score of 0.02 indicates a wide net was cast and reflects a high proportion of qualitative studies, editorials, and feasibility discussions, underscoring the nascent stage of empirical research in this domain. Although the authors expected a larger collection of relevant articles, there is no gold standard by which to know if, or how many, relevant articles were missed. Thus, the Recall of the search strategy, defined as the proportion of relevant articles retrieved, cannot be reliably calculated. The calculations for Precision and Recall are provided in Figure 2. There were no articles identified that described all the outcome measures of interest. Various combinations of outcomes were described in each article. Table 1 summarizes the distribution of quantitative outcomes for each of the 9 articles. These 9 articles were examined individually, and their basic methods and major findings are summarized in Table 2. The methodologies of the key articles were sufficiently unique so that head-to-head comparison of results would not be considered reliable. Although some articles were found in the broader search that describe randomized comparison groups,[33] these did not focus on the management of acute traumatic injury. Although we initially intended to conduct a systematic review with stratification of evidence, due to the heterogeneity of clinical contexts, patient populations, and study methodologies encountered in the selected literature the authors felt that use of the term "systematic review" was not appropriate.

Articles Addressing Specific Metrics

ISS - There were 6 articles that describe the Injury Severity Score (ISS) of the study population.[24-27,30,31] In each of these studies, it was found that patients who had a teleconsultation had a higher Injury Severity Score than the general trauma patient population. Most articles did not specify if higher injury severity was a selection criterion for analyzing telemedicine results. However, Rogers et al describe a selection process that typifies the criteria for high-level activations, including hypotension, respiratory distress, truncal trauma, proximal amputations, and depressed Glasgow Coma Score.[32] While ISS cannot be used as a patient selection criterion since it is a post-hoc metric, each of these articles suggests that telemedicine poses the greatest benefit in severely injured patients, who may need more complex medical and surgical management, where early guidance from a trauma expert could contribute the most value. It is important to consider that the teleconsultation groups are typically more severely injured when comparing other outcome measures.

Mortality

There were 4 articles that reported a mortality comparison.[25,26,30,31] Mohr and Duchesne reported no

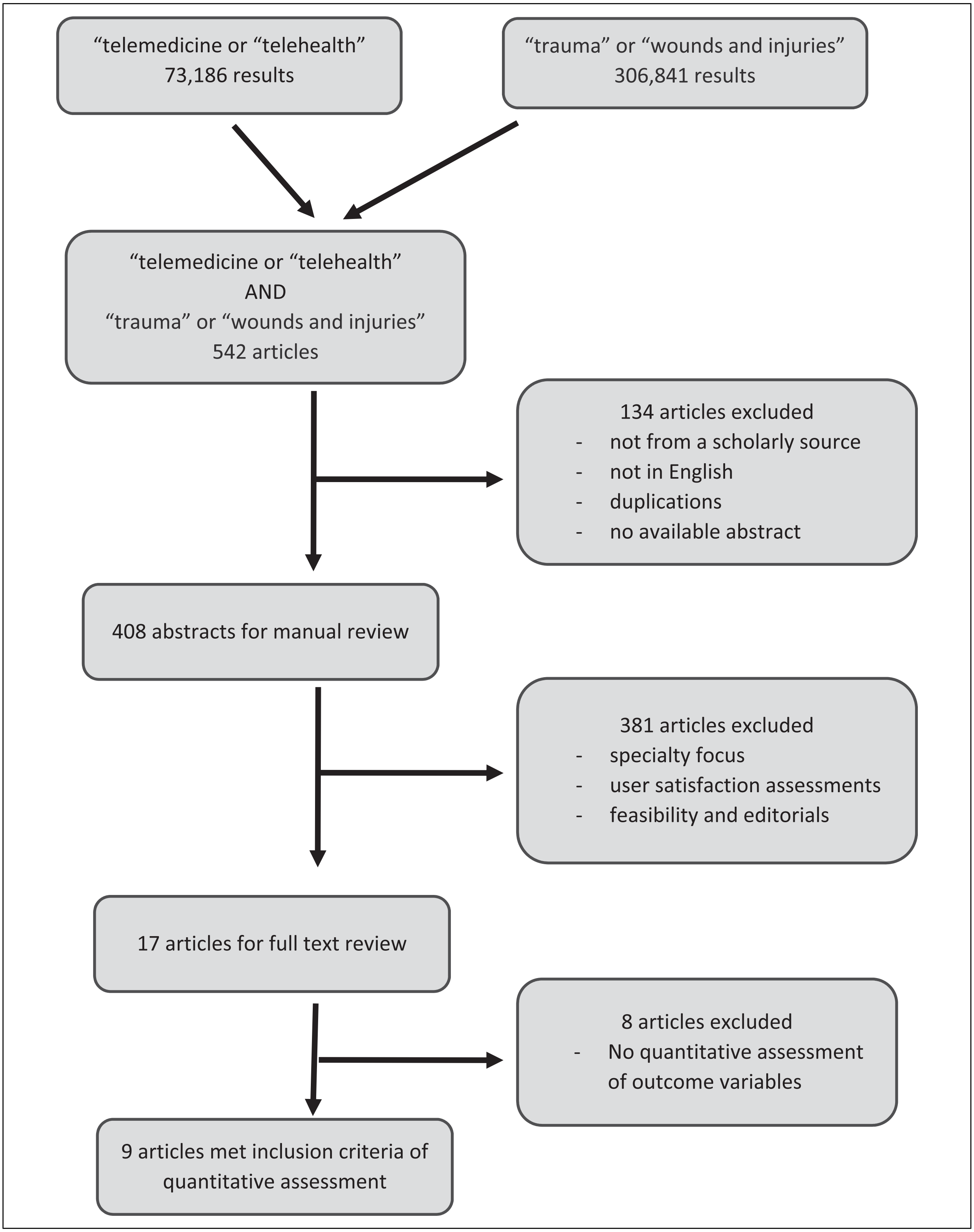

Figure 1. Search terms and article selection process. Legend: Calculation of search method accuracy based on relevance. Precision is the fraction of relevant instances among the retrieved instances. Recall is the fraction of relevant instances that were retrieved.

Precision and Recall

Precision (also called positive predictive value)	relevant retrieved articles / all ***retrieved*** articles	$\frac{TP}{TP + FP}$
Recall (also known as sensitivity)	relevant retrieved articles / all ***relevant*** articles	$\frac{TP}{TP + FN}$

Figure 2. Precision and Recall.

Table 1. Presence of Outcome Measures in Telehealth-Related Trauma Studies.

Study	Injury Severity Score	Transfers	LOS	Mortality	Diagnostic Accuracy	Treatment Decisions
Mohr and Harland et al, 2017[19]	+	+	—	—	—	—
Mohr and Vakkalanka et al, 2017[20]	+	+	+	+	—	—
Duchesne et al, 2008[21]	+	+	+	+	—	—
Latifi et al, 2009[22]	+	+	—	—	—	+
Aucar et al, 1997[23]	—	—	—	—	+	—
Aucar et al, 1998[24]	—	—	—	—	+	—
Ricci et al, 2003[25]	+	+	+	+	—	—
Rogers et al, 2001[26]	+	+	—	+	—	+
Wang et al, 2016[27]	—	—	—	—	+	+

Distribution of quantitative primary outcome measures in each selected article.

association between TM use and mortality.[25,26] Ricci reported a significant difference in mortality between TM patients and those transferred without TM consultation (25% vs 6%). However, the significance disappeared when corrected for ISS.[26] Rogers reported a significantly higher mortality among TM patients than the general trauma population admitted to the trauma center (15.4% vs 4.4%, $P = 0.04$).[31] However, they also had significantly higher ISS. An adjusted analysis was not reported. Thus, there is insufficient evidence to support that TM increases or decreases mortality in the context of acute trauma, beyond the effect of injury severity.

Diagnostic Accuracy

There are 3 articles that address the diagnostic accuracy of remote evaluation of acute trauma patients.[28,29,32] Aucar, in a 2-phase study, first used remote observation[28] and then an interactive audio-video link[29] to measure concordance and discordance between remote documentation and in-person documentation of 44 clinical variables from an ATLS based protocol. The detailed findings are included in Table 2. The general conclusion was that remote evaluation of trauma patients can be performed accurately. Wang reported the rate of diagnostic changes based on telemedicine consultation but considered the remote expert to provide the definitive diagnosis rather than the onsite generalist.[32] Thus, it could be viewed that the diagnostic inaccuracy of in-person evaluation of trauma by non-experts is approximately 30%. No articles reported the rate at which diagnoses made remotely were subsequently changed after transfer to a trauma center. Although further evidence is required, these studies could be interpreted to support the position that remote evaluation of trauma patients may be considered non-inferior and possibly superior to in-person evaluation by non-experts.

Treatment Impact

While numerous articles mention an impact on treatment by TM, there are only 3 articles that report case-specific or quantitative information about TM guided treatment decisions in the real-time evaluation and management of trauma patients.[25,31,32] Latifi and Rogers describe case-specific interventions such as airway management or other pre-transfer procedural innervations in their series.[27,31] Latifi indicated that 6 of 17 (35%) of patients had potentially lifesaving interventions guided by

Table 2. Individual Study Summary.

Study	Structure	Key finding
Mohr and Harland et al, 2017[19]	Registry review comparison n = 301 with TM consultations; n = 2536 patients without TM consultations	Patients with a TM consultation had higher Injury Severity Score (OR = 1.26 per 10-point increase in ISS, 95% CI = 1.05 to 1.51) and higher interhospital transfer rates (56.5% vs 44.4%). The difference in interhospital transfers was not significant after adjusting for ISS and injury type
Mohr and Vakkalanka et al, 2017[20]	Registry review comparison n = 291 with TM consultations; n = 7209 patients without TM consultations	Patients with TM consultation had more frequent ISS >9 (44.3% vs 26.1%) A 30% shorter ED length of stay (95% CI 14.1-45.1) A higher transfer rate (51.5% vs 32.3%) No association between TM use and mortality (adjusted odds ratio = 0.9)
Duchesne et al, 2008[21]	Retrospective comparison of trauma patients evaluated with TM consultation between 7 rural hospitals and a single trauma center to historical controls. n = 463 with TM consultations n = 351 prior to TM program	Patients with TM consultation had lower transfer rate (11% vs 100%), a higher Injury Severity Score (18 vs 10, $P < 0.001$), reduced ED length of stay (1.5 hours vs 4.7 hours, $P < 0.001$), and no difference in mortality between the groups
Latifi et al, 2009[22]	Single cohort case series of TM consultations between 5 rural hospitals and a level I trauma center n = 59 TM consultations for trauma and general surgery n = 35 (59% of series) for trauma patients. There was no comparison group for the teleconsultation patients	77% (27/35) of patients with TM consultation for trauma were transferred to the trauma center 30% (8/27) had some surgical intervention while 70% (19/27) had nonoperative care. Reports individual cases where TM guided interventions were considered lifesaving
Aucar et al, 1997 (phase I only)[23]	Videotaped review of trauma resuscitations; level I trauma center; n = 24 patients; 44 clinical variables based on an ATLS protocol assesses accuracy (concordance/discordance) between remote observations and chart documentation	Concordance rates for categories of variables: Demographics: 70-100%, complete initial vs: 0%-42% (no temps recorded), ATLS primary survey: 88%-100%, ancillary studies: 50%-00%, secondary survey history: 88%-96%, complete secondary vs: 0%-13% (no temps recorded), physical exam: 63%-88%, and diagnosis and disposition: 13%-100%
Aucar et al, 1998 (phase II only)[24]	Real-time consultation between remote attending surgeon and 3rd year surgical resident within a level I trauma center. n = 17 patients with assessment of 44 clinical variables based on an ATLS protocol (primary survey, vs, history, exam, diagnosis, and disposition) assesses accuracy (concordance/discordance) between remote observations and chart documentation	Concordance rates for demographics: 92%, complete initial vs: 69%, ATLS primary survey: 76%, ancillary studies: 56%, secondary survey history: 78%, complete secondary vs: 56%, physical exam: 82%, and diagnosis and disposition: 76%
Ricci et al, 2003[25]	Mixed-methods (qualitative and quantitative) review of patients referred from rural hospitals to a single level I trauma center. Compared LOS, mortality, and transfer time. n = 41 tele-trauma patients compared to n = 483 transferred patients without tele-trauma consultation	Trauma patients in the telemedicine group had a significantly higher Injury Severity Score (25.3 vs 12.7, $P < 0.0001$) and mortality (25% vs 6%) The mortality difference disappeared when adjusted for ISS. LOS was not significantly different between groups (adjusted mean of 7.7 vs 6.6 days, $P = 0.53$) when adjusting for Injury Severity Score. There was a 10% reduction in time to arrival at the trauma center for the tele-trauma group
Rogers et al, 2001[26]	Mixed-methods, retrospective review of TM consultations from a level I trauma center to 4 rural hospitals compared to general trauma population not receiving TM consultation. n = 26 telemedicine trauma consults. n = 816 No telemedicine consult trauma patients compared to ISS and mortality	19 TM consult patients (73%) were transferred 6 TM consult patients (23%) remain at rural hospital for care 1 TM consult patient died at rural ED from ruptured aortic transection TM consultation patients had higher ISS (23.75 vs 10.5, $P = 0.0001$) TM consultation patients had higher mortality (15.4% vs 4.4%, $P = 0.04$) 2 cases had treatment impact at rural sites considered lifesaving
Wang et al, 2016[27]	Review of 11 987 telemedicine consultations over a 12-year period from rural hospitals in China to specialist at several hub hospitals. Injuries accounted for 1663 consultations, of which 336 (20.2%) were considered emergent. Examined the impact of TM on change in diagnosis, treatment, and additional workup	29.3% (488 of 1663) of injury cases had a diagnosis change by TM 61.4% (1021 of 1663) of injury cases had treatment changed by TM. Approximately 1/3 of these were based on a diagnosis change. 17.4% (290 0f 1663) had additional diagnostic work up recommended by TM

Methodology and findings of 9 quantitative reports on remote trauma evaluations.

telemedicine,[27] Whereas Rogers reports 2 of 26 (8%) of patients with similar circumstances.[31] Wang reports that remote consultation to a trauma expert resulted in treatment recommendations in approximately 60% of cases, half of which were associated with a change in diagnosis.[28]

Transfers

There were 6 studies that examined the impact of telemedicine on interhospital transfer rates or efficiency.[24–27,30,31] Of these, 2 studies report a higher transfer rate among patients who were the subject of telemedicine consultation compared to those who did not, (56.5% vs 44.4%)[24] and (51.5% vs 32.3%).[25] Both studies showed a higher ISS among TM patients, which sensibly correlates with higher transfer rates. The differences in transfer rates were not significant when corrected for injury severity and type. These articles likely represent overlapping patients. Both studies describe retrospective data analysis and do not indicate that TM use was selectively driven by injury severity. There were 4 studies suggesting that TM consultation may reduce the transfer rate.[26,27,30,31] However, 3 of these studies compare a cohort of TM patients to patients who were all transferred to their trauma center[26,30] to the general population of their trauma center[31] or lacked a comparison group.[27] Thus, they are not adequately structured to resolve the question. Duchesne reports a transfer rate of 11% among the TM cohort, suggesting there was not a selection bias for severely injured patients. Rogers describes a selection bias for severely injured patients in the TM cohort and reports a transfer rate of 73%. These patients had significantly higher ISS and mortality, suggesting that TM may be effective in selecting patients with the highest risks and preventing unnecessary transfer. Ricci reports that 31/41 (75.6%) of patients seen by TM were transferred to their trauma center. There was a selection bias for patients meeting first and second level activation criteria, but there was no comparison to their baseline transfer rates. Latifi reports a single cohort of 59 patients evaluated by TM, 35 (59%) of whom were evaluated for trauma. Of the trauma patients, 27 (77%) were transferred to the trauma center. The presence of variable methodologies, missing comparative groups and indistinct selection criteria, make it difficult to draw a firm conclusion regarding the effectiveness of TM consultation for reducing unnecessary transfers or selecting patients for expedited transfer.

Length of Stay

There were 3 articles that analyzed pre-transfer ED LOS.[25,26,30] Mohr and Vakkalanka reported an average decreased LOS at the first hospital of 29.6 minutes (95% CI 14.1 - 45.1) when Telemedicine was used. Duchesne reported a significant reduction in ED LOS in patients evaluated by TM, compared to case-matched historical controls (1.5 hours vs 4.7 hours, $P < 0.001$). Ricci did not report ED LOS but calculated total time from injury to arrival at the referral trauma center. TM patients had a 34.8-minute (10%) reduction in this time interval compared to transferred patients without TM evaluation. This was not statistically significant, attributable to a small sample size. This provides some evidence, if weak, that TM may reduce lingering time at referring facilities.

Discussion

Trauma care represents a quintessential model for the application of TM techniques. It is considered a specialty dependent on expert decision-making under diverse circumstances, associated with multiple opportunities for errors of omission, commission, and misprioritization. Yet, trauma cases often present in remote areas where access to experienced trauma surgeons is unavailable. This scarcity is exacerbated by the economies of scale.[34] The American College of Surgeons' Advanced Trauma Life Support (ATLS®) program teaches simultaneous treatment of life-threatening injuries, while the patient is fully evaluated and prepared for definitive care providing a framework to evaluate the effectiveness and efficiency of trauma resuscitations through a standardized approach. Telemedicine, by nature, is not a diagnostic test, subject to evaluations of sensitivity and specificity, nor is it a therapeutic intervention, subject to an assessment of safety and efficacy. Rather, it is a process of care that can theoretically be assessed by its impact on those outcomes. Based on the literature reviewed, there is a noticeable trend for researchers on the subject to use telemedicine preferentially for severely injured patients, with no clear evidence that it compromises care. As in most of the rest of the trauma literature, the articles reviewed here identify injury severity as the most prominent factor affecting mortality and no direct effect is identified for the process of care. Although the advocates of TM contend that it can save lives, current studies are not adequately structured and sufficiently powered to identify that effect.

There is support that TM for the acutely injured patient can provide a reliable and accurate diagnosis of injuries in a non-inferior way, because radiographic findings are a key component of the diagnostic process in trauma. The reliability of teleradiology was established elsewhere[35] and is not within this article's scope. However, TM may alter the extent of radiographic workup or advocate specific studies. While some diagnoses can be established radiographically without a trauma expert, the guidance of the radiographic workup and interpretation of the significance of results represents an expert-driven value that may be added remotely or in person. There is insufficient evidence to determine if this would decrease resource utilization or lead to increased costs based on overutilization. Telemedicine might possibly provide superiority to non-expert in-person evaluation, although reliable evidence to establish this remains sparse.

There is anecdotal and small series evidence that TM may invoke pre-transfer procedures, some lifesaving, but the applicability of this principle may be highly dependent on individual participants and their level of comfort with uncommon procedures. If the remote evaluation process is efficient, there may be a narrow window of time for pre-transfer treatment maneuvers to be implemented. This may lead to arguments analogous to the classic controversy between "scoop and run" vs "stay and play" in pre-hospital care.[36]

Existing literature does not adequately address the question of whether TM can reduce unnecessary transfers or expedite appropriate transfers, although there is some supporting evidence for both. The decision to transfer is driven by the sending hospital clinicians and is affected by the local resources and level of comfort. Yet, it has been established that unnecessary transfers consume excessive resources and represent a large burden on trauma centers,[37] whose limited resources are better focused on severely injured patients.

There is supportive evidence, although not high-level, that remote evaluation, invoked early, can reduce the ED length of stay at the remote hospital. This might be relevant to both patients being transferred and those staying or being discharged from the remote hospital. TM for acute trauma may also have a secondary favorable impact through education, ongoing training, and review of ATLS principles for non-experts at remote sites, potentially improving the quality of care available to injured patients. The findings of this review suggest that telemedicine is a viable mode of rural trauma care but should be monitored for quality outcomes and requires further quantitative research to establish safety and efficacy. Such efforts should be focused on clear patient selection and stratification criteria; identification of local resources and the telemedicine techniques utilized; conformity to ATLS protocols; specification of diagnostic data obtained, and diagnoses made at the referring site; identification of the impact of telemedicine consultation made on treatment or transfer processes; and identification of pitfalls encountered or avoided. Proper methodologies might include comparison of outcomes to propensity-matched or entropy balanced cohorts.

This study has several limitations. A large portion of the literature on TM for trauma consists of editorials, case reports and feasibility studies that lack scientific rigor and were excluded from our analysis. Thus, the impact they may have on our research questions is unrepresented. Current studies are conducted predominantly by receiving trauma centers that focus on transferred patients, with a selection bias for high-severity injuries and a bias to promote transfers. The lack of literature with randomized patient selection, standardized evaluation processes and technology, and appropriate control groups limits confident assessment of the outcome variables of interest. The highest level of evidence encountered is considered level 3, as defined by Elsevier Author Services, "Case-control study (therapeutic and prognostic studies); retrospective comparative study; study of nonconsecutive patients without consistently applied reference "gold" standard; analyses based on limited alternatives; and costs and poor estimates."[38] This review cannot claim any higher level of evidence through its summarized results. We did not attempt to address the cost or resource consumption of TM for trauma due to the wide variation in cost accounting, disparities in the organizational structures, resource leveraging, and rapidly changing technology cost. Despite the limitations, the value of this review comes from clarifying the state of the art in the use of telemedicine for trauma and identifying the conditions needed to improve scientific rigor on the subject.

Conclusions

Published findings provide low-level support for the relative accuracy of TM for diagnosis, guiding workup, and impact on treatment. TM may reduce pre-transfer length of stay, particularly in more severely injured patients. However, there is no identifiable impact on mortality based on current literature.

While there are many studies on the subject, there are few that take a quantitative approach. We believe this is the first review to critically assess the state of the art for using telemedicine for initial, acute trauma care, prior to identification of subspecialty needs and with a focus on quantitative assessments of key outcomes. These findings warrant more rigorous prospective studies on the utility of telemedicine for acute trauma.

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