Challenges to Real-Time Decision Support in Health Care

Mark Fitzgerald, MB, BS, FACEM; Nathan Farrow, RN, BN (Hons) Adv Nur (Critical Care); Pamela Scicluna, BSc; Angela Murray, RN; Yan Xiao, PhD;
Colin F. Mackenzie, MBChB, FRCA, FCCM

Abstract

This article describes challenges in the design and development of a decision support system for trauma patient resuscitation that is used to encourage consistency and reduce error rates. The Trauma Reception and Resuscitation Project links real-time, computer-generated prompts from best practice algorithms via visual and auditory displays. Its functionality is now being tested. Evaluation of this decision support approach can employ patient chart review or observation, but we describe an approach that measures the process of care by video audit. Key process problems in trauma management (e.g., errors of omission, commission, and misprioritization) are identified. The video record provides a framework for learning and feedback. Future testing and development of this system will include a randomized clinical trial and technology enhancement.

Introduction

The development, testing, and validation of a real-time decision support system for use during trauma patient reception and resuscitation present many challenges. The decision support system described in this article is part of the Trauma Reception and Resuscitation (TR & R) Project at The Alfred Hospital and Swinburne University of Technology in Melbourne, Australia. The hypothesis that inconsistency and medical errors can be reduced by use of a decision support tool is currently being tested in a randomized clinical trial. The TR & R Project concentrates on the first 30 minutes of trauma patients' hospital reception and resuscitation.[1] The types and causes of errors that occur in the complex dynamic medical domain of a trauma center and the need for decision support are described. An interdisciplinary approach to decision support development is outlined. Future output, testing, and development of the TR & R Project are described

Safety and Errors in Emergency Medical Care

Cognitive errors during emergency care are a significant contributor to patient harm. Approximately half the litigation brought against emergency physicians arises from delayed or missed diagnoses.[2] Traditionally, cognitive errors are classified into those of omission and commission. Omission errors are, in hindsight, events that occur through the natural progression of a disease, and they are noted as a tendency toward inaction. In a total error of omission, nothing has been done to achieve a goal; in a partial omission, some action has been taken. Errors of omission are more difficult to detect than those that can be attributed directly to the action of a physician.[2] In contrast, errors of commission result in harm to the patient that, in hindsight, could have been prevented by different or no interventions. Such errors are more likely to be committed by overconfident physicians. They include premature, irrelevant, redundant, unmotivated, and prohibited actions. Commission errors are less common than omission errors.[3]

The problems associated with medical errors of commission and omission become most apparent in complex clinical settings where decisionmaking is carried out under stress and time pressure, as in trauma patient resuscitation. Human limitations in performing reliably and consistently in challenging situations have been documented in high-hazard industries, such as shipping, electric power production, chemical manufacturing, and the military.[4] Efforts to improve patient safety and outcomes rely on strategies to ameliorate or eliminate the impact of human limitations.[5] A "culture of reliability" is needed to encourage uniform responses and conformity to standard operating procedures. Health care providers might reject such an approach because they fear loss of autonomy.

Human variables that confound standardized environments and thereby lead to avoidable errors have been delineated by the airline industry.[5, 6] To reduce critical error rates in that industry, computerized prompts have been built into flight control systems, providing immediate feedback and thus enhancing error avoidance.[5] In the TR & R Project, uniform and appropriate responses for the trauma team are guided by decision support software and the structured data generated by computer prompts.

Decision support algorithms for trauma resuscitation in emergency departments have been developed over the past 2 decades,[7, 8] in part, in an attempt to bring uniformity into complex environments that are often characterized by high staff turnover. Frequent changes in personnel result in a need for coordination of activities among team members who are trained in a variety of treatment approaches and have variable amounts of experience in a particular resuscitation workspace. Studies have demonstrated that formal trauma patient algorithms encourage consistency, reduce error rates, prevent cognitive overload, and significantly reduce resuscitation time.[9]

In the complex environment of receiving areas for patients with major trauma, communication remains problematic. Even when experienced clinicians are involved, communication of significant clinical decisions fails 50 percent of the time.[10] An important reason for preventable adverse events in clinical care was found to be cognitive overload of physicians. Evidence-based clinical guidelines can reduce variability in practice and improve patient outcomes.[8] However, clinical teams working in real time and providing emergency care do not have access to sufficient computer-based information to support their practice in this demanding environment. This is due to gaps in published clinical practice guidelines and also because trauma centers have been slow to adopt decision support systems.

Most errors that arise during the emergency department/trauma center phase of care relate to resuscitation.[11] Failure to intervene and reverse life-threatening conditions during this phase of care are related to inexperience, disorganized activity, an inability to organize priorities, fixation error, and failure to realize the complexities of the problem(s). The coordination of multiple activities[12] may be just as critical for patient survival as making the correct diagnoses or performing the most appropriate procedures. Errors in trauma resuscitation may have little immediate effect, yet they may eventually compromise patient outcome. Nonstandard and nonuniform approaches confound the interpretation of error rates and hamper the retrospective, subjective judgment of error.[13]

Implementation Issues

Algorithms

A new approach is required, using point-of-care, integrated resuscitation treatment algorithms and real-time, computer-generated prompts. Algorithms act as decision support systems that define the standard of care for trauma reception and resuscitation. The most rigorous application of algorithms in clinical decisionmaking involves rule-based computer systems. Bedside (point of care) computerized protocols that standardize clinical decisions for the mechanical ventilation of patients with adult respiratory distress syndrome have been used since 1992.[14] Clinical algorithms using a branched-tree logic approach have been used since the early 1980s to guide fluid resuscitation.[7] These algorithms have improved the outcomes of hypotensive patients in the emergency department,[15] encouraged consistency, and reduced resuscitation time and errors.[8]

Need for Decision Support Systems

During trauma patient resuscitation, errors occur due to uncertainty, time pressure, and communication failures among the members of ad hoc teams that often are brought together for a single patient encounter. Because of multitasking and inadequate information in this dynamic and complex environment, decisionmaking occurs under nonoptimal circumstances and could benefit from algorithm-based assistance.

During the initial resuscitation phase of trauma patient management, resources are in short supply, time is constrained, and shortcuts are being sought.[2] Decision support should facilitate what Reason called “flesh and blood” decisionmaking.[16] Diagnostic errors are associated with proportionately more morbidity than are other types of medical errors. Decisionmaking during trauma patient resuscitation is limited by poor access to information and limited time to process it in a milieu well known for error production,[2] where heuristics dominate. In an analysis of emergency department closed claims, Morey found that improved teamwork behaviors would have prevented an adverse event and indemnity payments in 43 percent of cases.[17] There is evidence that a standardized algorithmic approach reduces error, that real-time prompts increase compliance, and that video analysis improves accuracy and compliance.[13] Clinical algorithms linked to real-time decisionmaking, with an awareness of team coordination needs, can deliver patient-specific advice, thus integrating decision support into the clinical workflow (“process alignment”).[1]

Challenges in Emergency Trauma Care

The challenge of decisionmaking during emergency trauma care is that there is no consistent pattern of patient injury. The site and extent of injuries are unknown during the initial minutes after the patient is admitted to the trauma center. Team management for resuscitation is variable, with newer concepts (e.g., hypotensive resuscitation[18]) contradicting conventional [e.g., Advanced Trauma Life Support (ATLS)] training. There is a need for a variety of personnel with different training backgrounds, experience, and clinical disciplines (e.g., physicians, nurses, technicians, therapists) to work together in close physical proximity around the trauma patient.

Research findings have repeatedly demonstrated the difficulty of measuring the impact of a single intervention in a complex, nonstandardized environment with multiple variables.[13] The major variables in resuscitation include human factors, especially staff experience and expertise, and associated variability in resuscitation practices. Access to specific expertise may not be readily available. The typical clinician is affected by these stressors. Although clinicians make the right decisions most of the time, many of the interventions undertaken in these first few critical minutes may not be done at the right time, in the right amount, or in the right order.[7]

Considering these challenges in combination with the fact that 50 percent of emergency department communications fail, it is surprising that patient outcomes are as good as they are. The stimulus for the TR & R Project in Victoria was the finding by the Consultative Committee on Road Traffic Fatalities that 25 percent of trauma deaths in the state were preventable.[11] The committee reported that the emergency department phase of care was responsible for the greatest number of errors—a mean of 7.52 per patient.[11]

The human challenges to the study include the technology and psychomotor workload, preservation of confidentiality of video-recorded data, and obtaining consent and Institutional Review Board approval. Video recording can be a fruitful tool for the prospective evaluation of a decision support system.[19, 20, 21] However, challenges in deploying video recording technology are numerous.[22]

Long-running video recording programs, such as the one instituted at the University of Maryland, have utilized a number of techniques,[23] including transparency and communication with staff, technology solutions, and analytic approaches.[24] The main cost associated with audit is related to the personnel time involved. Video audit is a time-consuming task that requires dedicated support and funding. Linking computer-generated prompts via visual and auditory displays in the resuscitation bay may enhance clinicians' interactions and reduce errors of omission and miscommunication. The TR & R Project measures compliance with the prompts—rather than prelearned algorithms—using video audit. Such an approach may allow an objective and streamlined means of audit, reducing the time-consuming process associated with peer review.[13]

Products and Their Evaluation

TR & R Software Function

The treatment decision tools were developed after review of several hundred published algorithms—available for many resuscitation tasks and decisions—that were published in emergency medical, radiologic, anesthesiology, surgical, and nursing texts. The draft algorithms then underwent several levels of compliance testing of interfaces, screen displays, and content of the prompts. During this time, the clinical staff from The Alfred Trauma Centre went to the Swinburne University of Technology Laboratories to iteratively test the TR & R system and provide their feedback to the software developers. The final algorithms written into the TR & R software were agreed upon by consensus among emergency medical, radiologic imaging, surgical, anesthesiology, and nursing staff at The Alfred Trauma Centre. The TR & R software system is scalable and exportable, with computer-prompted algorithm displays for real time use on patients with major trauma.[1, 13] These algorithms define the standard of care for trauma patient resuscitation.

To facilitate maintenance and ensure robustness, the TR & R software architecture is modular and component-based. The modular design (Figure 1), developed by software engineers at Swinburne University of Technology, allows individual components to be replaced as existing hardware is upgraded (e.g., vital signs monitors, audiovisual equipment) and portions to be reused when the system is expanded as new capabilities are introduced. The algorithm designer is a separate custom built tool that allows the graphic representation of algorithms and customization of reference data (Figure 2) by medical staff themselves without intervention by the software developers. Software is written in an intuitive, easy language, in which the algorithms can be modified or new ones generated by the end users themselves. The data used by the algorithm engine are at the core of the trauma reception and resuscitation software (Figure 3). A video data acquisition system overlays patient monitoring data onto the video recording.[25] The audit tool utilizes the data outputs (Figure 4) for increased efficiency.

Measuring Errors and Algorithm Compliance

The traditional quality management approaches for improvement in future outcomes include mortality and morbidity (M&M) conferences,[26] completion of incident reports associated with each unexpected or preventable death, and corrective action, including clinician education and removal of causes of error. This approach takes a long time. The review of preventable deaths is usually done long after the event, and the lessons to be learned are diluted by the loss of immediate feedback.

The TR & R algorithm-driven treatment standard provides an objective video audit tool that is used to measure compliance with real-time prompts, overcoming the subjective nature, human variation, and flawed reliability of expert opinion, which have been critical weaknesses in preventable mortality studies to date. The audit, to monitor compliance with the algorithmic prompts, is accomplished by reviewing video recordings of resuscitation. The video record has the patient’s physiologic signs overlaid.

In the ongoing randomized clinical trial of the TR & R system, two of the four resuscitation bays at The Alfred Trauma Center have displays of the prompts; the other two bays are control bays with video audit of resuscitation but no decision support. In addition, a historical control group performing trauma patient resuscitations was recorded before the decision support software became available. Subject matter experts reviewed the video images made in all four resuscitation bays to establish management differences with and without the prompts.

Using the framework of the algorithms, a standardized method for procedures and decisionmaking was agreed upon by the investigators involved in the TR & R Project. Start and end times for procedures were defined, and appropriate timing of decisions was identified, so that there was no ambiguity or subjectivity in reviewing the video records. Inter-rater reliability analysis confirmed the validity of the video audit parameters. Video recording minimizes the occurrence of hindsight bias, as occurs in reviewing a case at an M & M[26] conference, when knowledge of the outcome may influence the perception of past events.

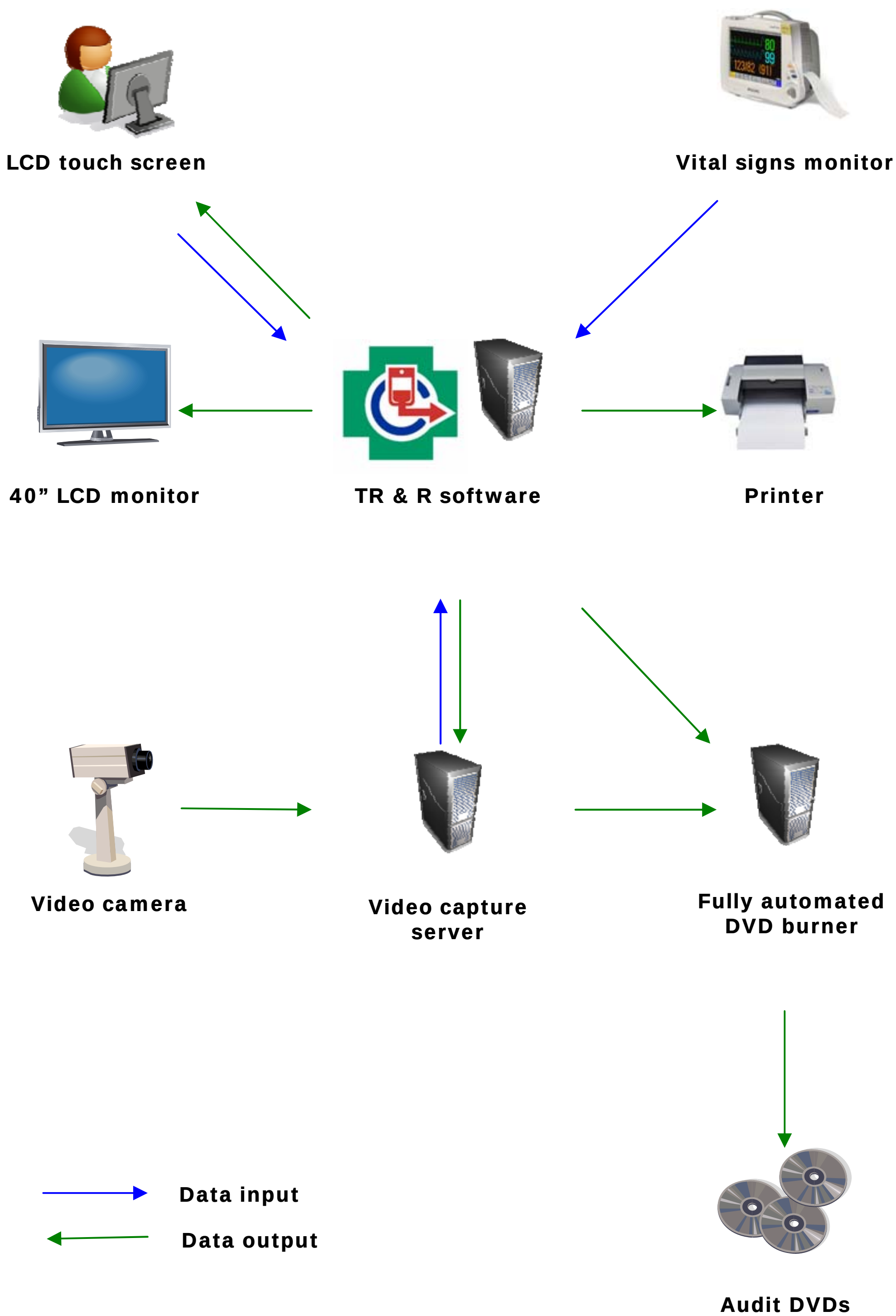

Figure 1. TR & R hardware.

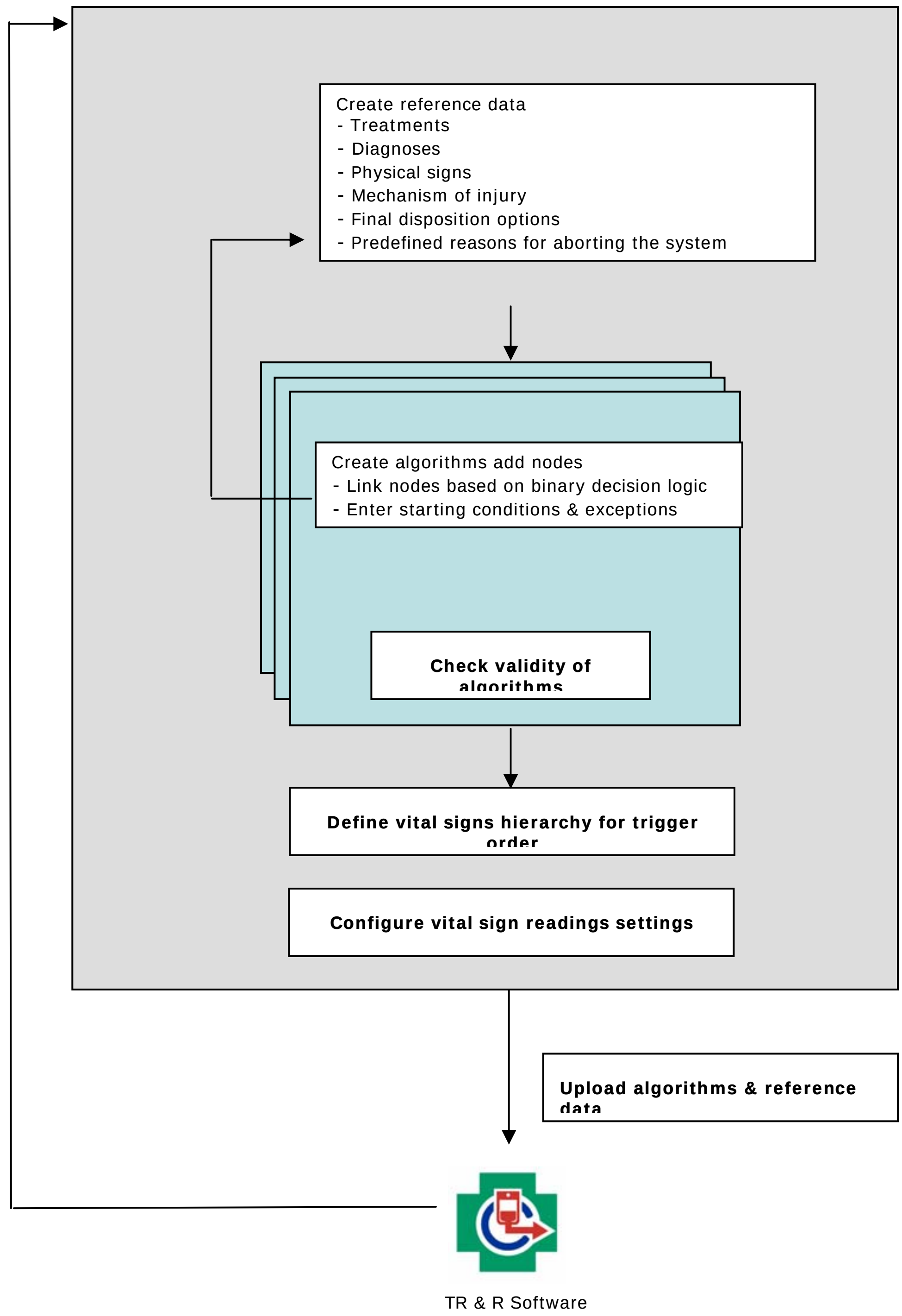

Figure 2. TR & R algorithm design process.

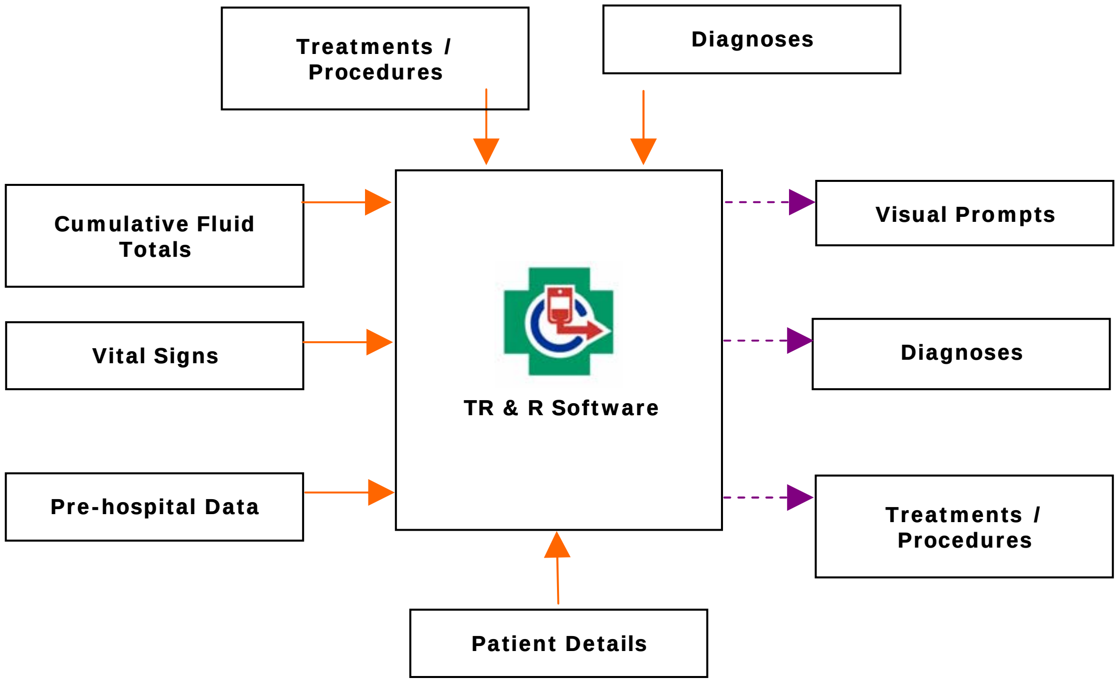

Figure 3. Algorithm engine data input/outputs.

Review of all cases of trauma patient reception and resuscitation is necessary to identify the relationship between process and outcome. A preliminary cohort of video records of trauma reception and resuscitation was made during the 3 months before the TR & R decision support software was installed. Analysis facilitated the development of performance measures, which included documentation of prehospital data and primary and secondary survey resuscitation landmarks. Note is made of the administration of adequate fluids, blood, and components; adequate bleeding assessment and control; warming; monitoring; and requests for appropriate tests and investigations.

Impact of the TR & R Project on Advancing Decision Support

Current methods of reporting errors made during the care of trauma patients usually rely on adherence to ATLS® protocols, missed diagnoses, improved outcomes (typically using historical controls), and preventable deaths using cohort comparison.[27, 28, 29] Previously described medical decision support systems are rigid, not well integrated with the medical record, and lack capabilities for robust evaluation. The compliance of medical staff with prelearned guidelines remains problematic. Although reviews demonstrate improvements, compliance with algorithms is rarely measured in real time. Recognition of preventable error is usually retrospective rather than current.

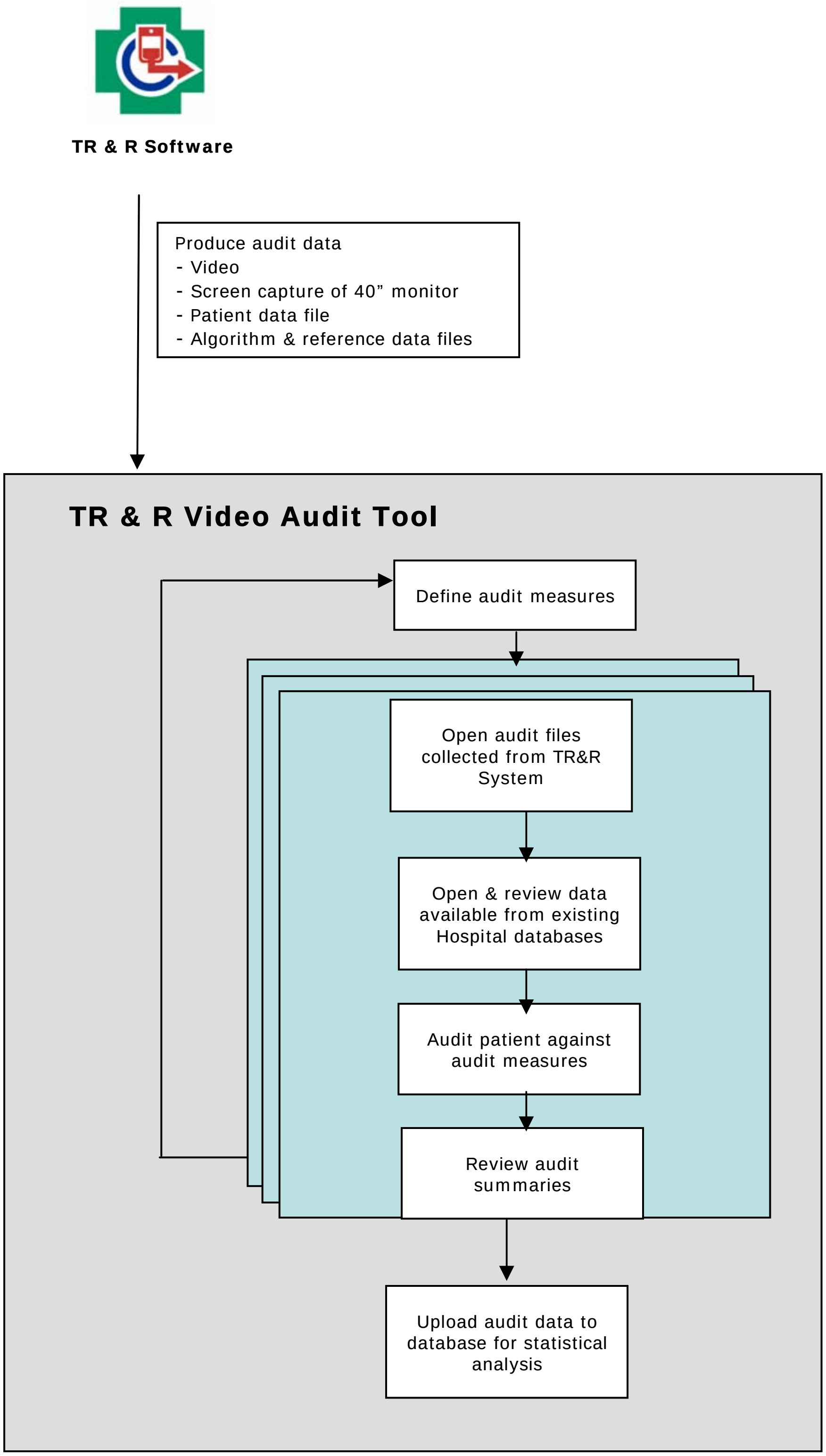

Figure 4. TR & R video audit process.

In comparison, the TR & R Project software advances decision support by collecting data in real time (for later review by video audit in the randomized clinical trial) and allowing detection of response to decision support prompts. Such an approach allows iterative validation of the decision support system's performance and identification of details about clinician performance not found in other quality improvement processes.[13]

Future Implementation

Possible Improvements

Most decision support systems have incomplete automation of data entry that activates the treatment algorithms, even though the need for complete data entry automation is widely acknowledged.[30] Usually a nurse or other experienced expert needs to be employed to enter clinical interventions and decisions that drive the decision support software. In the TR & R software, a scribe enters data manually at a terminal during resuscitation. These data then determine which algorithms, interventions, and decisions are displayed on a large LCD screen in the resuscitation bay. The branches of algorithmic decision trees (many can be active simultaneously) are displayed in real time.

Automation of data entry by voice recognition software (using a limited vocabulary to maximize accuracy) and other simple tools used by the resuscitation team leader would be a huge improvement in the utility of such a system. The plan would be to determine the limited vocabulary needed for accurate voice recognition by extraction of communications from existing audio-video records of reception and resuscitation. The software would need to be validated and bench-tested for accuracy and waveform data collection. After such an automated system is validated, it could be used to test the hypotheses that (1) automated data entry provides decision prompts equally effectively as scribe-entered data, and (2) the introduction of real-time, computer-prompted algorithms will measurably reduce management errors and protocol recruitment failures associated with reception and resuscitation.

Because so many errors occur during the time-critical and dynamic first 30 minutes of trauma patient resuscitation, it is possible that this effort might not be totally successful. A further refinement of the system might include minimizing the impact of an error by identifying redundancies, which would make the clinician reconsider a decision not carried out after being promoted by the algorithm. When time stressors are excessive, the decision support system could suggest task-shedding strategies to achieve lifesaving interventions expeditiously and allow less essential processes to be held back. When time allows, the clinician could be reminded with a prompt stating that the procedure still needs to be completed after patient stabilization.

The trauma reception and resuscitation software provides multiple simultaneous algorithmic decision supports in real time, continuously collects waveforms of vital signs, and provides a basis for activating research protocol recruitment and a definitive record by video audit of the vital first 30 minutes of resuscitation. A summary document is produced and can be entered into the patient chart as the official record of resuscitation care (Figure 5).

TRAUMA RECEPTION & RESUSCITATION SUMMARY (UP TO 30 MINUTES)

PATIENT DETAILS

Arrival Time: 17:17 06-Aug-2007
Age: 32
Weight: 70kg
Gender: Male
Incident Location: Williamstown
Triage Category: 1
Trapped: No
Trapped Duration:
Mechanism of Injury: Motor vehicle driver, No Seat Belt, car vs tree 60km/hr ejected

OBSERVATIONS

Time	Pulse	BP	RR	GCS	E	V	M	Temp	SpO2	EtCC
17:23	110	95/-	28	14	4	4	6	-	95	-
17:19	132	80/62	32	12	3	4	5	34	90	-
-	128	85/52	28	14	4	4	6	-	92	-

CONFIRMED DIAGNOSES

Closed Pneumothorax Right
Cardiac tamponade
Hypothermia
Pupils equal and reacting.r3l3

UNCONFIRMED DIAGNOSES

R Rib fractures ?
Shock
Closed head injury/cerebral concussion
R Compound Fractured Femur
Lacerations Forehead

FLUID AND DRUG TOTALS

Crystalloid IV infusion 500ml
Maxolon 10mg
Morphine 20mg

TREATMENTS

Time	Treatment
-	Needle decompression Right
-	L 18 G Peripheral IV insertion
-	Maxolon 10mg
-	Crystalloid IV infusion 500ml
-	Splint cervical spine
-	L Traction (Donway) splint lower limb
-	Dressing Forehead
-	Morphine 20mg
17:17	12 l/min via mask O2
17:19	FAST
17:20	12 l/min via mask O2
17:20	12 l/min via mask O2
17:20	Order O -ve blood 5 Units PRBC
17:20	ECG monitor
17:20	SpO2 monitor
17:20	Non invasive BP Blood Pressure monitoring
17:21	actively Rewarm patient

DISPOSITION AFTER INITIAL TRAUMA RESUSCITATION (up to 30 minutes)

Transfer to CT

COMMENTS

Signature

Print name & designation

Please staple to Trauma Resuscitation Record MR B-82
06/08/2007 17:27:25

Figure 5. Trauma reception and resuscitation summary (up to 30 minutes)

A future improvement could include the integration of laboratory results and radiographs into the LCD screen display and multisite or even mobile wireless “heads up” displays rather than a single screen. The video and other records associated with trauma patient resuscitation could become part of that patient’s electronic health record. In the future, remote direction of trauma reception and resuscitation via telecommunication links would be a natural advance of the decision support system, such that a single expert could direct patient management in multiple remote locations simultaneously.[30, 31]

Future Testing and Goals

The TR & R software system is in daily use at The Alfred Trauma Center for the prospective, controlled, randomized trial that is evaluating its effectiveness. The video audit is used to verify compliance, error rates, and subsequent patient outcomes. Outcome measurements include compliance with prompts, error rate per patient, missed diagnoses, and time to major interventions. The goal is to reduce error through standardized decisionmaking, leading to a reduction in both preventable mortality and morbidity among patients with major trauma. Among the important functions of the TR & R Project are the standardization of resuscitation documentation, interventions, and diagnoses. The algorithms will be published, and there will be a critical evaluation of the cost-benefit of video audit to measure compliance with algorithms in real time.

Web technology (e.g., ProtoVIEW™ from Infragistics, Inc., Cranbury, NJ, USA) could be used to build a fast and easy flexible protocol information system. A wide range of diagnostic and therapeutic protocols can be retrieved and viewed with ProtoVIEW. It contains a radiograph viewer and provides a great deal of interactivity, such as validation of electronic patient data forms. An additional function of ProtoVIEW is the context-sensitive protocol support that could lead to improved protocol adherence.[30] A Web-based TR & R decision support system for trauma care would be a future goal, allowing remote access from multiple locations in the field and in hospitals during resuscitation and during the intensive care management of trauma patients.

Conclusion

The need for improvements in real-time medical decision support is recognized in both the civilian and military care of trauma patients.[31] The TR & R Project is an ongoing research effort that is actively testing a decision support system through a prospective randomized clinical trial. The video audit of errors of commission and omission and the documentation of clinicians’ interaction with the system will determine whether such a system can reduce errors and improve trauma patient outcome.

Author Affiliations

Emergency & Trauma Centre, The Alfred Hospital, Melbourne, Australia (Dr. Fitzgerald); The National Trauma Research Institute, Melbourne, Australia (Dr. Fitzgerald, Mr. Farrow, Ms. Murray); Swinburne University of Technology, Melbourne, Australia (Ms. Scicluna); The Shock

Trauma Center, Department of Anesthesiology, University of Maryland School of Medicine, Baltimore, MD (Dr. Xiao); The National Study Center for Trauma and Emergency Medical Systems, Baltimore, MD (Dr. Xiao, Dr. Mackenzie).

Address correspondence to: Mark Fitzgerald, The Alfred Hospital, Commercial Road, Melbourne, VIC 3004, Australia; e-mail: m.fitzgerald@alfred.org.au

References

1. Fitzgerald M, Bystizycki A, Farron N, et al. Trauma reception and resuscitation. Aust NZ J. Surg 2006; 76: 725-728.
2. Crosskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. Acad Med 2003; 78: 775-780.
3. Clarke JR, Spejewski B, Gertner AS, et al. An objective analysis of process errors in trauma resuscitation. Acad Emerg Med 2000; 7: 1303-1311.
4. Gaba DM Structural and organizational issues in patient safety: A comparison of health care to other high-hazard industries. Calif Man Rev 2000; 43: 83-102.
5. Heimreich R. On error management: Lessons from aviation. Br Med J 2000; 320: 83-102.
6. Billings CE, Ryenard WD. Human factors in aircraft incidents: Results of a 7-year study. Aviat Space Environ Med 1984; 55: 960-965.
7. Shoemaker W. Resuscitation algorithms in acute emergency conditions. In: Grenvik A, Ayres SM, Holbrook PR, et al, eds. Textbook of critical care. 4th edition. Philadelphia: WB Saunders; 2000. p. 49-59.
8. Bishop M, Shoemaker WC, Jackson G, et al. Evaluation of a blunt and penetrating trauma algorithm for truncal injury. Crit Care Clin 1991; 7: 383-399.
9. Grimshaw JM, Russell IT. Effect of clinical guidelines on medical practice: A systematic review of rigorous evaluations. Lancet 1993; 342: 1317-1322.
10. Bergs E, Rutten F, Tadros T, et al. Communication during trauma resuscitation: Do we know what is happening? Injury 2005; 36: 905-911.
11. McDermott FT, Cordner SM, Tremayne AB. A “before and after” assessment of the influence of the new Victorian trauma care system (1997-1998 vs 2001-2003) on the emergency and clinical management of road traffic fatalities in Victoria. Victoria, Australia: Report of the Consultative Committee on Road Traffic Fatalities; 2003 Dec.
12. Xiao Y, Hunter A, Jefferies N, et al. Task complexity in emergency medical care and its implications for team coordination. Hum Fact 1996; 38: 636-645.
13. Fitzgerald M, Gocentas R, Dziukas L, et al. Using video audit to improve trauma resuscitation – time for a new approach. J Can Chir 2006; 49: 208-211.
14. East TD, Bohm SH, Wallace CJ, et al. A successful computerized protocol for clinical management of pressure control inverse ratio ventilation in ARDS patients. Chest 1992; 101: 697-710.
15. Hopkins JA, Shoemaker WC, Chang PC, et al. Clinical trial of an emergency resuscitation algorithm. Crit Care Med 1983; 11: 621-629.
16. Reason J. Human error. New York: Cambridge University Press; 1990.
17. Morey JC. Error reduction and performance improvement in the emergency department through formal teamwork training: Evaluation results of the MedTeams project. Health Serv Res 2002; 37: 1553-1558.
18. Dutton R, Mackenzie CF, Scalea TM. Hypotensive resuscitation during active hemorrhage: Impact on in-hospital mortality. J Trauma 2002; 52: 1141-1142.
19. Hoyt DB, Shackford SR, Fridland PH, et al. Video recording trauma resuscitations: An effective teaching technique. J Trauma 1988; 28: 435-440.
20. McCormick DP, Rassin GM, Stroup-Benham CA, et al. Use of videotaping to evaluate pediatric resident performance of health supervision examinations of infants. Pediatrics 1993; 92: 116-120.
21. Xiao Y, Seagull FJ, Bochicchio GV, et al. Video-based training increases sterile technique compliance during central venous catheter insertion. Crit Care Med 2007; 35: 1302-1306.
22. Butler DJ, Englert L. On the rise and fall of videotaping programs. Fam Med 2001; 33: 89-90.
23. Mackenzie CF, Craig GR, Parr MJ, et al. Video analysis of two emergency tracheal intubations identifies flawed decision-making. Anesthesiology, 1994; 81: 763-771.

24. Mackenzie CF, Xiao Y, Hu FM, et al. Video as a tool for improving tracheal intubation tasks for emergency medical and trauma care. Ann Emerg Med 2007; 50: 436-442.

25. Mackenzie CF, Hu PFM, Horst RL, et al. An audio-video acquisition system for automated remote monitoring in the clinical environment. J Clin Mont 1995; 11: 335-341.

26. Kossman T. The need to move on from mortality to morbidity outcome predictions ANZ Surg 2005; 75: 623.

27. Houshian S, Larsen MS, Holm C. Missed injuries in a level 1 trauma center. J Trauma 2005; 52: 715-719.

28. Sampalis JS, Boukas S, Lavoie A, et al. Preventable death evaluation of the appropriateness of on-site trauma care provided by Urgeneces-Sante physicians. J Trauma 1995; 39: 1027-1028.

29. Frankel HL, Fitzpatrick MK, Gaskell S, et al. Strategies to improve compliance with evidence-based clinical management guidelines. J Am Coll Surg 1999; 189: 533-538.

30. Vissers MC, Hasman A. Building a flexible protocol information system with ready for use web technology. Int J Med Inform 1999; 53: 163-174.

31. Osheroff JA, Teich JM, Middleton BF, et al. A roadmap for national action on clinical decision support. JAMIA 2007; 14: 141-145.