Trauma Surgery & Acute Care Open

Defining adverse events during trauma resuscitation: a modified RAND Delphi study

Brodie Nolan ,[1,2] Andrew Petrosoniak,[1,2] Christopher M Hicks,[1,2] Michael W Cripps,[3] Ryan P Dumas[4]

[1]Emergency Medicine, St Michael's Hospital, Toronto, Ontario, Canada
[2]Department of Medicine, Division of Emergency Medicine, University of Toronto, Toronto, Ontario, Canada
[3]Surgery, University of Texas Southwestern Medical Center at Dallas, Dallas, Texas, USA
[4]Department of Surgery, UT Southwestern Medical, Dallas, Texas, USA

Correspondence to
Dr Brodie Nolan; brodie.nolan@mail.utoronto.ca

Received 14 July 2021
Accepted 22 September 2021

To cite: Nolan B, Petrosoniak A, Hicks CM, *et al*. *Trauma Surg Acute Care Open* 2021;**6**:e000805.

ABSTRACT

Background The majority of preventable adverse event (AEs) in trauma care occur during the initial phase of resuscitation, often within the trauma bay. However, there is significant heterogeneity in reporting these AEs that limits performance comparisons between hospitals and trauma systems. The objective of this study was to create a taxonomy of AEs that occur during trauma resuscitation and a corresponding classification system to assign a degree of harm.

Methods This study used a modified RAND Delphi methodology to establish a taxonomy of AEs in trauma and a degree of harm classification system. A systematic review informed the preliminary list of AEs. An interdisciplinary panel of 22 trauma experts rated these AEs through two rounds of online surveys and a final consensus meeting. Consensus was defined as 80% for each AE and the final checklist.

Results The Delphi panel consisted of 22 multidisciplinary trauma experts. A list of 57 evidence-informed AEs was revised and expanded during the modified Delphi process into a finalized list of 67 AEs. Each AE was classified based on degree of harm on a scale from I (no harm) to V (death).

Discussion This study developed a taxonomy of 67 AEs that occur during the initial phases of a trauma resuscitation with a corresponding degree of harm classification. This taxonomy serves to support a standardized evaluation of trauma care between centers and regions.

Level of evidence Level 5.

INTRODUCTION

The management of critically injured patients requires a rapid assessment and simultaneous prioritization of resuscitative maneuvers. Most preventable adverse events (AEs) occur during this initial phase of resuscitation in the trauma bay.[1] An inquest of traumatic deaths revealed an average of 6.09 AEs per fatal trauma case, with 3.47 AEs directly attributed to the patient's death.[2] These AEs include failure to perform therapeutic or diagnostic measures at the right time, lack of familiarity with an injury pattern, disorganized staff or equipment, failure to prioritize or realize complexity, fixation errors, and misdiagnosis.[2] One study estimated errors in communication to occur in over 50% of trauma cases.[3] The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) Patient Safety Event Taxonomy was created to facilitate a common approach for patient safety information systems.[4] Not all AEs lead to patient harm and having a classification system for the degree of harm is an important adjunct to a taxonomy of AEs. While the JCAHO degree of harm categorization is helpful, the JCAHO classification may not fully account for the complexity that exists in trauma care and a trauma-specific taxonomy is needed.

A limitation of prior studies evaluating AEs in trauma is the absence of a standardized taxonomy of AEs, resulting in significant heterogeneity in the reporting of AEs and impairing the comparison of AEs across trauma centers. Identified AEs from previous studies are often recognized through morbidity and mortality reviews, which are primarily physician driven and lack the input and expertise of non-physician healthcare providers.[5] The creation of a taxonomy of AEs with input from experts of various interprofessional backgrounds represents an opportunity to standardize how hospitals assess quality improvement (QI) and patient safety initiatives for trauma resuscitation.

The objective of this study was to create a taxonomy of AEs that occur during trauma resuscitation that are relevant to all professions of the trauma team. Additionally, we sought to create a degree of harm classification system that can be used with this taxonomy.

METHODS

Study design

A modified RAND/UCLA (RAND Corporation/University of California at Los Angeles) Appropriateness Method Delphi study was used to establish a list of adverse events that occur during acute trauma resuscitation.[6] The study was conducted between October 2020 and February 2021. This study is reported according to the recommendations for CREDES (Conducting and REporting of DElphi Studies).[7] Participants were required to sign informed consent forms before participating in the study.

Justification

The Delphi approach is a widely used, rigorous, and accepted method in healthcare for obtaining expert consensus through an iterative ranking process.[6] By choosing a RAND/UCLA Appropriateness Method we sought feedback from expert participants, and they were allowed to suggest and edit the list of AEs. No patients or public were involved in this study because the opinion of trauma experts was the main objective.

Initial AE list development

Trauma resuscitation was defined as the period of time when a patient enters the trauma bay or resuscitation room on first presentation to hospital until the time of departure from this space. The initial Delphi survey was assembled by the team of investigators who are researchers and clinicians from emergency medicine and trauma surgery. An initial list of AEs based on a completed systematic review and clinical experience was drafted by BN.[5] This list was then shared with the investigating team that included two emergency physician/trauma team leaders who are experts in human factors and medical education (AP, CMH) and two trauma surgeons with expertise in trauma team assessment (RPD, MWC). Each team member added additional AEs based on their perspectives. This initial list contained 57 AEs that were grouped into categories of trauma resuscitation.

Additionally, the investigating team drafted a degree of harm classification scale that was based on the JCAHO classification of degree of harm.[4]

Selection of participants

We sought to achieve representation from typical members of a trauma team including trauma surgeons, anesthesiologists, emergency physicians, nurses and respiratory therapists. We used a non-probability purposive sample of 20 participants invited via email. Sampling was purposive to ensure that invited participants met the inclusion criteria: fluent in English, older than 18 years of age, fully licensed in their respective discipline and involved in a combination of clinical, educational and research trauma resuscitation. Each member of the research team submitted a list of trauma management experts for study participation. We then used a snowball sampling technique to maximize recruitment from other national and international institutions where participants were asked to identify additional experts. Experts were blinded to the identity of other Delphi group members until the final consensus meeting, and participant responses were deidentified before data analysis.

Estimates of appropriate sample sizes for Delphi processes differ depending on the makeup of the target population; however, when participants have similar training and expertise, smaller sample sizes of 20–30 participants have been shown to be adequate.[8] Therefore, we aimed to recruit at least 20 participants to complete all rounds.

Delphi process

Participation in the modified Delphi process involved two web-based survey rounds and a final videoconference (figure 1). Each participant was contacted by the study coordinator who also exclusively received all survey responses. The research team was blinded to the identity of all participants. In round 1, participants received the list of 57 AEs developed from a systematic review.[5] Participants were asked to rate AEs on a scale of 1–7:

- 1–3: Not important, should not be included in the final list of adverse events.
- 4–6: Important, should be included in the final list of adverse events.
- 7: Critical or severe adverse event.

Participants were able to provide feedback on suggested wording and ask questions or clarification around listed AEs. In round 1, participants were invited to suggest additional AEs beyond those listed. Throughout this process, all participants were blinded to the identity and specific comments of the other study participants and received only summarized comments during each round to mitigate any bias that may have been associated with others' feedback. In round 1, experts were asked to rank each grade of the proposed degree of harm classification system as either agree or disagree and were asked to provide comments or feedback.

After round 1, participant comments were reviewed and consolidated. The mean for each AE was calculated, and AEs with a mean ≤3.0 were removed from the next round.[9–11] In round 2, the process was repeated using the revised list of AEs developed from the preceding round. The stopping criterion for

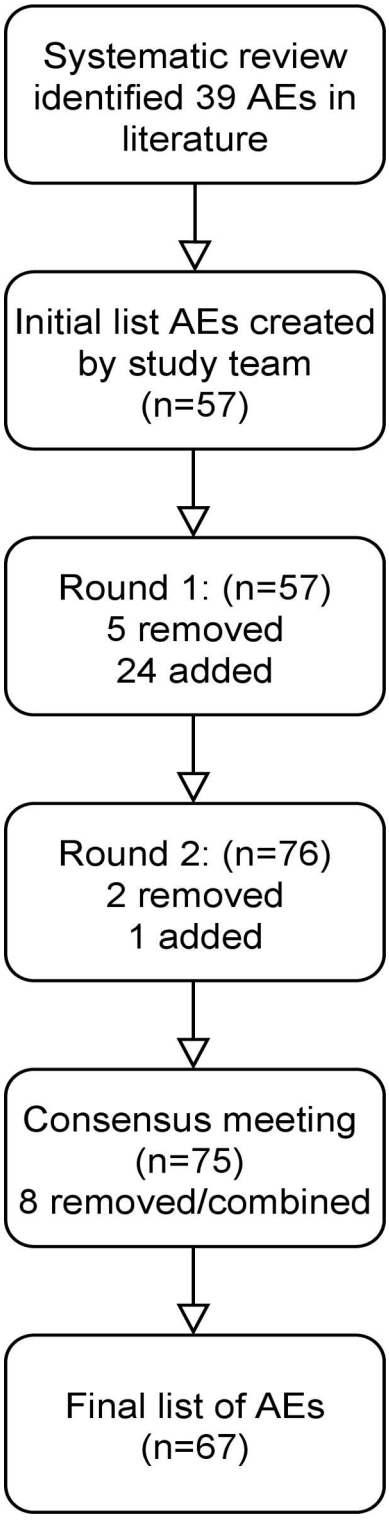

Figure 1 Delphi study overview. AE, adverse event.

Table 1 Demographic characteristics of participants

Profession	n (%)
Trauma surgeon	11 (50.0)
Emergency medicine physician	5 (22.8)
Nurse	4 (18.2)
Anesthesiologist	1 (4.5)
Respiratory therapist	1 (4.5)
Years in practice, mean (SD)	8.2 (6.6)
Country of practice	**n (%)**
Canada	15 (68.2)
USA	7 (31.8)

the study was either consensus on 80% of AEs or no change in the mean score for any AEs between two consecutive rounds. This resulted in two rounds taking place.

After round 2, a final consensus meeting was held by videoconference in February 2021. In preparation for the consensus meeting, the research team put together the latest draft of AEs as revised during round 2. The meeting started with a presentation on the study purpose and set-up, followed by a moderated group discussion. During this consensus meeting, participants were asked to confirm the AEs they had identified as being important to include in the final taxonomy. When differences in opinion hampered the process, decisions were made through consensus, where a >75% majority was needed for amending an AE. Throughout the meeting, proposed changes to AEs were projected on a screen in real time. The meeting was audio recorded and comments and changes were recorded by a research team member. The video recording of the meeting was sent out to all participants for review if they were unable to attend.

Statistical analysis

Data were exported from SurveyMonkey into Microsoft Excel V.16 (Microsoft, Washington, USA) for calculation of descriptive statistics. Data were presented as frequencies, proportions, mean (SD), or median (IQR).

RESULTS

Participants

A total of 22 experts were recruited from various medical backgrounds (table 1). All participants were actively working in a patient-forward position at a level 1 or 2 trauma center.

Delphi process

Two rounds were performed before the consensus was met. A final consensus meeting was held via videoconference after round 2. All 22 (100%) participants completed both rounds of surveys and 17 of the 22 (77.3%) participated in the final consensus meeting.

Round 1

Of the 57 AEs included in the first round, five of them were removed as they did not meet the >3.0 mean rating or had critical concerns from reviewers. The remaining 52 AEs met the consensus criteria of >80% of participants rating them 4–7. Thirteen of these AEs had wording revised to improve clarity based on participant feedback. An additional 24 AEs were proposed by the expert participants during this round.

The degree of harm classification had 95% to 100% agreement of participants. There was no additional feedback or changes proposed.

Round 2

In round 2, participants were provided with the revised wording of AEs during round 1 and voted on the additional 24 AEs proposed in round 1. During this round, two AEs were removed as they did not meet the >3.0 mean rating. The remaining 22 AEs were rated 4–7 by >80% of the participants. Five of the AEs during this round were revised for clarity based on participant feedback and one additional AE was proposed.

Consensus meeting

Once consensus was achieved, which occurred after round 2, the consensus meeting was held. All 75 AEs included in the study up to this point were discussed at the consensus meeting. During this meeting, eight AEs were discussed to be redundant, or non-meaningful and were either eliminated or absorbed into another AE through revision of wording. In the end, the participants agreed that 67 AEs should be grouped into nine categories to create the final taxonomy of AEs in trauma (table 2).

DISCUSSION

Major findings

Using a modified RAND Delphi procedure, this study established a taxonomy of 67 trauma AEs grouped into nine categories: airway and breathing, circulation, emergency medical service handover, assessment of injuries, management of injuries, procedure related, patient monitoring and access, disposition, and team communications and dynamics. Additionally, a proposed degree of harm classification system was created to be used with the AE taxonomy (box 1).

Meaning of the findings

This taxonomy of AEs provides the framework for a standardized analysis of both intrafacility and interfacility trauma resuscitations. Additionally, this taxonomy can serve as the foundation for targeted QI and patient safety initiatives including video review.[12–16] By integrating this taxonomy into an institutional trauma video review program, reproducible and reliable analyses can occur. A common language and understanding of AEs applied during the video review process may allow for more accurate comparisons of trauma resuscitations and a more comprehensive understanding of the sequence of events leading to the AE. For example, repeated occurrences of 'unintentional delay in intubation' support the development of a shared mental model among those tasked with QI and system development. Once it is established that a particular AE is recurrent then detailed investigations can be undertaken to determine what system and process-level interventions are required. Such an approach emulates the systems thinking approach that is common across other high-risk industries.

Although consensus was reached across multiple professions for all AEs, there were some that were considered critical by only one or two professions. Most often these involved AEs that were deemed to be critical by nurses and not physicians (such as failure to provide the patient with unique hospital ID or bracelet within 5 minutes of arrival). During the consensus meeting, the downstream effects to delayed patient identification and registration were brought up, such as delays to activation of a massive transfusion protocol and blood product delivery, or the challenges during a recent mass casualty incident with multiple

Table 2 Final taxonomy of adverse events that occur during acute trauma resuscitation

Airway and breathing
- Failure to identify need for supplemental oxygen.
- Unanticipated loss of airway.
- Unintentional delay in intubation (>5 min).
- Unsuccessful intubation attempt.
- Malpositioned endotracheal tube.
- Aspiration event.
- Ventilator malfunction.
- Failure to identify need for chest tube.
- Failure to perform surgical airway when indicated.
- Administration of paralytics prior to all teams ready.
- Failure to discuss, anticipate, or treat hemodynamic instability prior to intubation.

Circulation
- Failure to obtain peripheral or central venous access within 5 min of first attempt.
- Failure to draw bloodwork within 10 min of arrival.
- Delay of >10 min to blood product administration (once blood is called for).
- Delay to administration of blood products to set up rapid infuser.
- Greater than 1 L crystalloid bolus given in presumed hemorrhagic shock.
- Failure to administer blood products or initiate vasopressors with ongoing shock (SBP <90).
- Failure to activate massive transfusion protocol (if more than 2 units of blood products required).
- Failure to control ongoing external bleeding.
- Failure to identify/treat worsening hemodynamics or level of consciousness.
- Failure to administer TXA in presumed hemorrhagic shock and injury <3 hours.
- Failure to give platelets or fresh frozen plasma if >6 units of blood product given in trauma bay (ie, only pRBC given).
- Primary resuscitative line is subdiaphragmatic (ie, femoral line, tibial IO) in patients with positive FAST or open book pelvis

EMS handover
- Failure or delay to activate trauma team.
- Inaccurate or incomplete medical history report.
- Team member(s) absent for EMS handover.
- Patient assessment begins before EMS handover in stable patients.

Management of injuries
- Medication error.
- Failure to treat hypothermia.
- Failure to apply or incorrect application of pelvic binder in the setting of open book pelvic fracture.
- Failure to offer effective analgesia/sedation to patients.
- Failure to reduce fracture/dislocation in setting of pulseless limb.
- Failure to provide patients with unique hospital ID or bracelet within 5 min of arrival.
- Failure to administer hypertonic saline or mannitol in setting or presumed head injury with lateralizing signs or unilateral pupil deficit.

Assessment of injuries
- Failure to maintain cervical spine precautions (if indicated).
- Failure to get X-rays before departure from trauma bay (if indicated).
- Failure to complete primary survey before departure from trauma bay.
- X-ray misinterpreted.
- FAST misinterpreted.
- Incomplete exposure of patients.
- Failure to calculate GCS.
- Failure to measure temperature.
- Failure to assess circulation and function in injured limbs.

Disposition
- Delay more than 15 min waiting for CT.
- Delay more than 15 min waiting for OR (if emergent OR).
- Transfer to CT scan with hemodynamically unstable patients.

Procedure related
- Technical errors.
- Equipment failure/missing.
- Failure to perform an indicated resuscitative procedure.
- Iatrogenic injury during procedure.
- Knowledge deficits concerning equipment location.
- Performing FAST examination interferes with ability to obtain initial intravenous access.
- Bodily fluid exposure or needlestick injury to healthcare team member.

Team communications and dynamics
- Unclear responsibility and roles.
- Patient care activities delayed or not completed due to task overload/competing priorities.
- Team member unavailable.
- Concurrent conversations preventing team leader communication.
- Ineffective team leadership/unclear authority of team leader.
- Failure to use closed-loop communication.
- Clinical team members distracted by non-clinical-related tasks (ie, answering phone).
- Inadequate personal protective equipment.
- Trauma team leader leaves position to participate in patient care without delegating interim leader.

Patient monitoring and access
- Inadequate monitoring (ie, loss of telemetry, pulse oximetry for >3 min).
- Failure of patient-monitoring equipment (ie, patient monitor, $EtCO_2$, temperature probe).
- Oxygen supply runs out.
- Loss of all central/intravenous access.
- Delay in assessment or treatment due to agitated or combative patients.

EMS, emergency medical services; $EtCO_2$, end-tidal carbon dioxide; FAST, focused abdominal sonography in trauma; GCS, Glasgow Coma Scale; ID, identification; OR, operating room; pRBC, packed red blood cells; SBP, systolic blood pressure; TXA, tranexamic acid.

unidentified patients who needed blood products. A greater proportion of nurses also rated more AEs as critical compared with physicians. This highlights the importance of multidisciplinary review teams to obtain these different perspectives. Disagreement between professions regarding what constitutes an AE can lead to communication breakdown and pose risks to patient safety.[17] Educational or simulation interventions could focus on establishing a common understanding of the perspective of all trauma team members.

Strengths of the study

Although the initial list of AEs was developed from a systematic review and input from the coinvestigative team, we used the modified RAND Delphi procedure to improve its validity and generalizability. Additionally, we had a 100% response rate to both rounds of the Delphi. The inclusion of an interprofessional Delphi panel including physicians, surgeons, nurses and respiratory therapists also offered insight into AEs that are critical to some professions and may have been otherwise unidentified.

Limitations

We acknowledge several limitations of this study. The Delphi panel consisted of experts from multiple institutions and clinical disciplines; however, it notably only contained participants from North America and therefore was not representative of other continents. The expert panel consisted of a majority of physicians (rather than non-physician clinicians) which may have influenced ratings. Additionally, as the consensus meeting was not anonymous, participants may have felt hesitant to speak freely or bias may have been introduced by one individual's opinion being over-represented.[18] The study team attempted to mitigate this by including a chat function during the consensus call so that all Delphi members were able to comment throughout the meeting. Additionally, a recording of the consensus meeting was sent to

Box 1 Degree of harm classification

I. No harm
Definition: No harm or no detectable harm to patient occurred.
Examples: Delay in obtaining intravenous access in a stable patient, emergency medical service having to repeat patient information during handover.
II. Low harm
Definition: Minimal or temporary harm to patient that required little or no intervention.
Examples: Oversedation resulting in need for supplemental oxygen, lack of closed loop communication resulting in delay to administering analgesia.
III. Moderate harm
Definition: Temporary or permanent harm to patient requiring procedural intervention.
Examples: Oversedation resulting in need for oral airway, iatrogenic pneumothorax as a result of central line placement.
IV. Severe harm
Definition: Temporary or permanent harm to patient requiring intervention necessary to sustain life.
Examples: Inability to intubate resulting in severe hypoxia or temporary loss of pulse, failure to recognize tension pneumothorax resulting in temporary loss of pulse.
V. Death
Definition: Death of patient.
Example: Inability to intubate resulting in cardiac arrest and death, intubation of patient with known cardiac tamponade resulting in death.

all participants for final review and to elicit any additional feedback. Although Delphi consensus groups can produce collective answers, the achieved consensus is not necessarily valid.[18 19] Still, they can identify areas of focus for future research, which is especially true for our study on AEs in trauma. Future research could focus on establishing the validity and reliability of measuring the taxonomy of AEs and degree of harm system proposed in this study, with further refinement of definitions and terms to improve the accuracy of measuring these AEs.

CONCLUSION

This study systematically established a taxonomy and harm categorization of 67 AEs that occur during trauma resuscitation. This taxonomy can be applied at several levels to standardize the evaluation of trauma care including local and regional QI initiatives, and multicenter research collaborations. Future studies are needed to assess the validity and reliability of these AEs and explore the relationship between AEs and in-hospital outcomes.

Acknowledgements The authors would like to express their appreciation to Melissa McGowan, Emma O'Neil and the members of the Delphi panel for their important contribution to this study.

Contributors BN, AP, CMH, MWC and RPD conceived and designed the study. BN obtained research ethics approval, performed the data collection and analyzed the data. BN and RPD drafted the article, and all authors contributed substantially to its revision. BN accepts full responsibility for the finished work, the conduct of the study, had access to the data, and controlled the decision to publish.

Funding BN was supported by the Physician Services (grant number: PSI 19-29). BN and CMH were supported by the St Michael's Hospital Association Alternate Funds Plan (grant number: SMH 20-023).

Disclaimer The funders did not have a role in study design, data analysis, interpretation of the results, writing the article or submitting the article for publication.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Ethics approval was obtained through the St Michael's Hospital Research Ethics Board (REB 20-002).

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available upon reasonable request. Data are available on reasonable request to the first author. Data consist only of deidentified participant data during the two stages of the Delphi procedure.

ORCID iD
Brodie Nolan http://orcid.org/0000-0003-2872-0643

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