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A Study to Evaluate the Effectiveness of Simulation on Anaesthetic Non-Technical Skills in the Management of Major Trauma Patients

Velitchka Schembri Agius, Fiona Sammut, Tanya Esposito, Stephen Sciberras, John Mckenna

***Abstract*—**Background: Dynamic, challenging instances during the management of major trauma patients require optimal team intervention to ensure patient safety and effective crisis management. These factors highlight the importance of increased awareness in both technical and non-technical skills (NTS) training. Simulation based training (SBT) is an effective tool that replicates and teaches the required clinical skills, resulting in teamwork improvement, better patient safety, and care. Aims: This study investigates change in NTS, during the management of major trauma patients, using SBT. We also investigated the relationship between NTS performance and participation in previous NTS workshop (NTSW), years of experience, previous simulation (PS), previous exposure to major trauma patient management (MTPM) and group size. Methods: NTS behaviours were assessed by a single rater using previously validated framework for observing and rating Anaesthetists' Non-Technical Skills (ANTS) for anaesthetists and Anaesthetic Non-Technical Skills for Anaesthetic Practitioners (ANTS-AP) for anaesthetic nurses during SBT. Two anaesthetists (one senior, one junior) together with one to four registered anaesthetic nurses formed 17 teams. The SBT consisted of 3 major trauma scenarios: 1) Major haemorrhage following multiple stab wounds to the torso, 2) Traumatic brain injury complicated by unanticipated difficult intubation, and 3) Penetrating neck injury with major haemorrhage, complicated by a failed intubation. The scores of each NTS category for each scenario are evaluated for significance in change and used to correlate whether NTS during the simulation were affected by previous NTSW, PS, previous exposure to MTPM, and group size. Results: The resulting anaesthetists and anaesthetic nurses' p-values were < 0.05 indicating a significant improvement in all NTS resulting from score differences between scenarios 1 & 2 and 1 & 3. Anaesthetists' NTS categories were not influenced by PS, previous NTSW, and exposure to MTPM. However, anaesthetic nurses' NTS categories were influenced by PS, exposure to MTPM but not by NTSW. Conclusions: SBT has shown to be effective in improving the NTS for both anaesthetists and anaesthetic nurses. This enhances safety and team performance for MTPM. The impact of SBT in the clinical environment for patient management and safety warrants further research.

***Keywords*—**Simulation, major trauma, non-technical skills, crisis management, teamwork.

I. Introduction

MANAGEMENT of major trauma patients provides challenging and dynamic crises which requires optimal team interventions to ensure quality care. The growing importance of patient safety and effective crisis management has led to an increased awareness in technical and non-technical skills training [1]. Crisis management specialists have found the use of SBT as an effective tool to replicate highly dynamic environments, and teach the heterogenous skills required [2], [3]. Through SBT, practitioners improved clinical skills, practiced teamwork competencies, and developed strategies to handle exceptional events [2]. SBT minimised "learning on the job" instances, leading to enhanced workplace safety and improved patient care [4], [5]. Moreover, SBT demonstrated effectiveness in the development of behavioural components crucial for effective teamwork. Observations remark that anaesthetic teams' interactions notably varied during crisis management [6]. By definition, NTS are "cognitive, social and personal resource skills that compliment technical skills, and contribute to safe and efficient task performance" [7], [8]. NTS deficiencies increase the chance of error, exacerbating adverse events [8], [9]. 80% of 'human errors' originate from non-technical deficiencies, rather than lack of knowledge or equipment failure [10]. Common failings include: inadequate monitoring, drug cross-check failures, and poor communication. The latter is highlighted as the main deficiency in 78% of malpractice claims. Practising effective NTS including situation awareness, leadership and communication, has been endorsed as an essential error mitigation competency in the operating theatre [9]. The ANTS and the ANTS-AP provide a common language for NTS development; their discussion in everyday and emergency situations, enhances task safety, effectiveness, and efficiency [10], [11].

Aims and Hypothesis

The study's main objective was to assess change in NTS, utilizing an established ANTS/ANT-AP framework for the anaesthetic team during the management of major trauma patients using SBT. The secondary objective was to study whether a relationship between NTS performance and previous NTSW attendance, years of experience, PS, previous exposure to MTPM and group size, existed. The main hypothesis is that SBT improves NTS during management of major trauma patients.

II. Methodology

This paper is a single blinded observational study of behaviours of anaesthetic doctors and nurses during operating theatre major trauma simulation scenarios. Ethical permissions were obtained from the University of Malta. Approvals were also acquired from the Chief Executive Officer, the Anaesthesia department Chairman, Nursing Management and

Velitchka Schembri Agius is with the University of Malta, Malta (e-mail: vschembriagius@gmail.com).

the data protection board of Mater Dei Hospital (MDH), Malta.

Participants and Recruitment

41 anaesthetic nurses and 34 anaesthetic doctors from the MDH were voluntarily enrolled using e-mail invitations. The participants were randomly assigned into 17 teams and each participant was allowed a single session. The teams were made up of two anaesthetists - one senior (consultant or resident specialist) and one junior (resident specialist or trainee); together with one to four registered anaesthetic nurses. All participants received pre-simulation course reading material which included: Management of Massive haemorrhage (local guidelines) [12], World Health Organization (WHO) Trauma checklist [13], Difficult Airway Society (DAS) guidelines [14] and an article by Tobin et al. [15]. All candidates had previous experience of working together in both emergency and elective procedures; however, they were never exposed to the scenarios used in the study. To prevent dissemination of scenarios details, informed consent and confidentiality agreements were obtained from each participant on the day of the simulation. All participants enrolled completed the study.

Inclusion and Exclusion Criteria

Participants included were specialised or in-training anaesthetic doctors or registered anaesthetic nurses working at MDH with more than 6 months working experience in anaesthesia. Other non-anaesthetic specialities were excluded.

Environment

The simulation took place at the simulation centre of MDH. This centre is equipped with a simulated operating theatre. A high fidelity simulator mannequin (SimMan3G) was used with physiological parameters and observations initiated by a scenario operator were standardized for all teams. All drugs and equipment required during the scenarios were provided. No audio or visual recordings were taken during the simulations. An orientation of the simulation centre, equipment, and logistics were explained to the participants prior to simulation initiation.

The Scenarios

All 17 SBT sessions were identical and conducted by the same 3 instructors; who were assigned one specific role for all the sessions. The instructors' roles were defined as: a scenario operator, a NTS trained instructor collecting real-time data; and an instructor for logistics and debriefs. A trial run of each scenario was carried out to ensure good quality and timing. Each SBT session consisted of 3 major trauma scenarios presented in the same order. Upon scenario disclosure, participants were allowed 5 minutes for initial discussion and preparation. Each scenario and its' respective debriefing, was allocated 30 minutes.

Scenario 1 - Major Haemorrhage

- 21 year old male with multiple stab wounds to the torso (2 stab wounds to the right chest, 1 stab wound in the right hypochondrium, 1 stab wound to the epigastrium)
- Positive focused assessment with sonography in trauma (FAST) scan
- Haemodynamically unstable- systolic blood pressure = 70 mmHg
- Insertion of right sided chest drain for right tension pneumothorax
- Damage control resuscitation, with activation of major haemorrhage protocol
- Proceeding with damage control laparotomy (liver laceration).

Scenario 2 - Traumatic Brain Injury

- 70 year old male on warfarin for atrial fibrillation (fell 5 stairs)
- Requiring an emergency evacuation of right subdural haemorrhage with midline shift: a drop in Glasgow coma score (GCS) from 15 (E4V5M6) to 7 (E2V2M3)
- Raised intracranial pressure management
- Unanticipated difficult intubation with a can't intubate can't oxygenate (CICO) scenario requiring emergency cricothyroidotomy as per DAS guidelines [14]
- Surgical airway confirmed with capnography and improvement in oxygen saturation.

Scenario 3 - Penetrating Left Sided Neck Injury (Zone 2)

- 30 year old female hemodynamically unstable from major haemorrhage, complicated by a failed intubation due an expanding neck haematoma
- Trachea is intubated via a supraglottic airway device using fiberoptic bronchoscope and confirmed with capnography as per DAS guidelines[14]
- Control and repair of the major neck vessels by surgical team
- Balanced transfusion after activation of major haemorrhage protocol [12].

Measurement Instruments and Outcomes

NTS assessments were carried out using previously validated framework for observing and rating ANTS for anaesthetists [10] and ANTS-AP for anaesthetic nurses [11]. ANTS include 4 categories: task management (TM), teamwork (TW), situation awareness (SA) and decision making (DM) [10]; whereas the ANTS-AP includes 3 categories: SA, teamwork/communication (TW/C) and TM [11]. A 4-point scoring system was used to rate the behaviours of each category. Each scenario was scored separately, with each candidate being assigned a total score for each category (Tables I A-C). The overall scores ranged from: 4 to 16 for the ANTS rating system, and 3 to 12 for the ANTS-AP rating system [11].

At the end of the simulation participants were asked for the following information:

- Gender
- Years of anaesthesia experience
- Rank (Anaesthesia Consultant/Resident Specialist/ Trainee/Nurse)
- Previous exposure to MTPM (Yes/No)

- Previous experience in simulation (Yes/No)
- Previous attendance to NTSW (Yes/No)

Statistical Analysis

The statistical analysis was performed using the SPSS 25.0 software. The scores for each NTS category in all 3 scenarios were evaluated for significance in change. Comparisons were conducted between the first and second scenario, as well as the first and third scenario. The scenarios' scores were also used to correlate whether NTS during the simulation of major trauma were affected by previous attendance to NTSW, PS and previous exposure to MTPM.

The Mann-Whitney U-test was used to correlate years of experience with: previous NTSW, PS, and previous exposure MTPM. The same test was used to correlate the NTS variable of scenario 1 with: previous NTSW, PS, and previous exposure MTPM; following a normality check with Shapiro-Wilk test. To compare the change in scores between scenarios, the Wilcoxon signed-rank test was used. All tests with a p-value of < 0.05 were considered significant.

TABLE I A
ANTS TOOL FOR ASSESSING THE ANAESTHETIST GROUP [10] (MAX = MAXIMUM)

Category	Element	Element Rating	Category Rating
TM	• Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilizing resources	Max 4 each	Max 16
TW	• Coordinating activities with the team • Exchanging information • Using authority and assertiveness • Assessing capabilities	Max 4 each	Max 16
SA	• Supporting others • Gathering information • Recognising and understanding • Anticipating	Max 4 each	Max 16
DM	• Identifying options • Balancing risks and selecting options • Re-evaluating	Max 4 each	Max 12

TABLE I B
ANTS-AP TOOL FOR ASSESSING THE ANAESTHETIC NURSES GROUP [11] (MAX = MAXIMUM)

Category	Element	Element Rating	Category Rating
SA	• Gathering information • Recognizing and understanding • Anticipating	Max 4 each	Max 12
TW/C	• Coordinating with the team • Supporting Colleagues • Asserting	Max 4 each	Max 12
TM	• Planning and preparing • Prioritizing and problem solving	Max 4 each	Max 8

TABLE I C
ANTS AND ANTS-AP RATING SYSTEM [10], [11]

Rating	Description
4-Good	High standard performance and patient safety
3-Acceptable	Satisfactory performance with room for improvement
2-Marginal	Cause for concern, which requires considerable improvement in performance
1- Poor	Potentially dangerous to patient-safety, corrective actions required
N-Not observed	Skill not observed or required

III. RESULTS

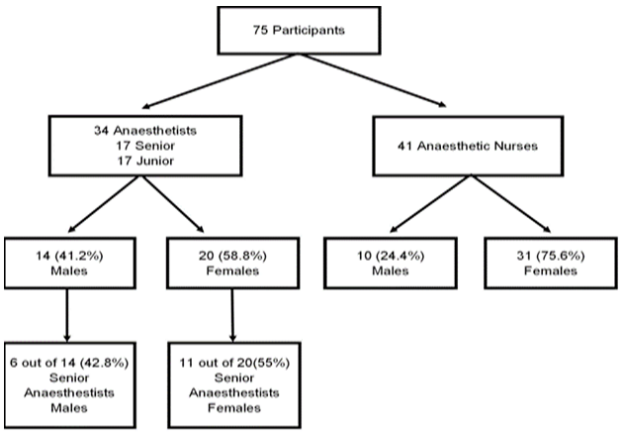

Fig. 1 Participants' Demographics

Fig. 1 shows the participants' demographics enrolled in the study. Tables II A and B illustrate the frequency of MTPM, PS and NTSW of the participants before the study.

TABLE II A
ANAESTHETISTS FREQUENCY TABLE

Anaesthetists	Exposure to major trauma patients' Management (MTPM)		PS		Previous NTSW	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Yes	31	91.2	29	85.3	27	79.4
No	3	8.8	5	14.7	7	20.6
Total	34	100	34	100	34	100

TABLE II B
ANAESTHETIC NURSES FREQUENCY TABLE

Anaesthetic Nurses	Exposure to major trauma patients' Management (MTPM)		PS		Previous NTSW	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Yes	37	90.2	20	48.8	26	63.4
No	4	9.8	21	51.2	15	36.6
Total	41	100	41	100	41	100

Years of experience of the participating anaesthetists ranged from 0.5 years to 30 years with an average of 10.71 years. The anaesthetic nurses' age ranged from 0.5 to 31 years, with an average of 6.87 years. All senior anaesthetists had previous experience with MTPM, with 3 junior anaesthetists registering no exposure. The majority of anaesthetists in both ranks experienced PS; 14 senior and 15 junior anaesthetists. The work experience classification of the 5 anaesthetists with no PS exposure was: 1 with 12 years, 3 with 17 to 20 years, and 1 with 30 years of experience. Conversely, 75.9% of the anaesthetists who experienced PS had up to 15 years of experience.

The average years of experience for PS were 9.214 and 19.4 for the no PS group, indicating that participants with higher experience lacked SBT exposure (Fig. 2 (a)). The years of experience for the anaesthetists PS group were considerably spread out in comparison with the candidates with no simulation experience. Standard deviation between the two groups was 7.765 and 6.6182 respectively. The median years of experience was 6.5 and 18 years respectively.

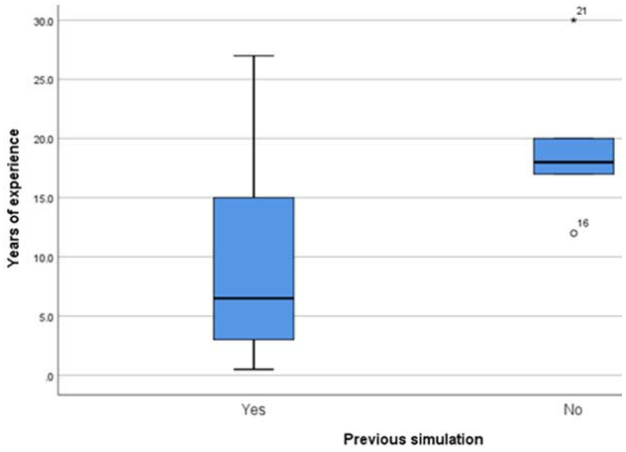

Fig. 2 (a) Box Plot - Year of experience vs. PS for Anaesthetists

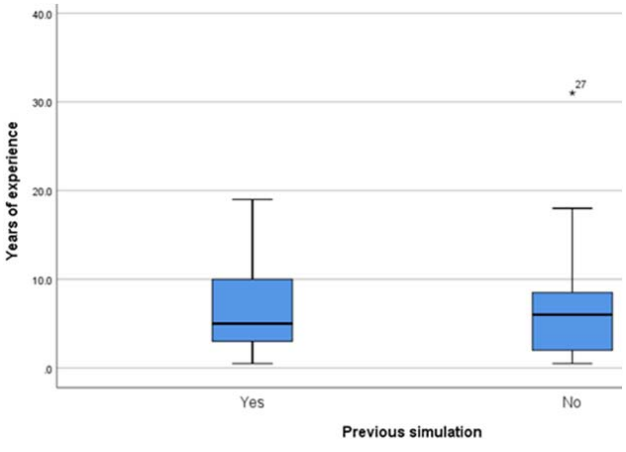

Fig. 2 (b) Box plot - Years of experience vs PS for anaesthetic nurses

Fig. 2 (b) displays anaesthetic nurses' years of experience with PS. The median number of years of experience for those who have never experienced simulation is slightly higher than the PS group (6 versus 5). However, the variance obtained from the group with no PS (51.515),was remarkably larger than the variance for the PS group (28.828). This development was a consequence of participant #27's data, who stood out from the anaesthetic nurses' group with 31 years of experience and no simulation experience. Excluding participant #27 from the anaesthetic nurses group, new 'trimmed' values were calculated. The two averages were 6.49 (PS) versus 7.238 (No PS); whilst the resulting mean for the number of years for the two groups (PS and no PS) was closer with 6.128 versus 6.327.

15 senior and 12 junior anaesthetists experienced previous NTSW. 'NO' Previous NTSW and 'NO' exposure to MTPM, was specified by anaesthetists with less work experience. Anaesthetists with less than three years' experience had never experienced MTPM. 4 anaesthetic nurses with less than one year of experience replied 'NO' when queried about previous MTPM encounters.

Considering several participants had no PS, no previous NTSW and no exposure to MTPM, it was of particular interest to test the influence of these variables on the scores achieved during scenario 1. The four variables during scenario 1 indicated that the majority of anaesthetists obtained the highest possible score. Out of 34 anaesthetists: 22 scored full points in TM; 19 in TW; 20 in SA; and 19 in DM. As for the anaesthetic nurses' during scenario 1, the top score for all three variables was only achieved by a relatively small percentage. Higher scores were achieved in scenario 3 for all the categories.

In order to test for significant difference in NTS category scores achieved in scenario 1 due to PS, previous NTSW and exposure to MTPM, testing for normality on the different subgroups of the data needed to be conducted first using the Shapiro-Wilk test. The resulting p-values for the different subgroups for the four NTS categories of interest were < 0.05. The Mann-Whitney test was used to determine whether a significant difference existed in the NTS category scores that resulted in scenario 1 was due to PS, previous NTSW and exposure to MTPM. The corresponding anaesthetist p-values were > 0.05, showing that the scores obtained for TM, TW, SA and DM were not influenced by PS, previous NTSW and exposure to MTPM (Table III A). The anaesthetic nursing group p-values that resulted for previous NTSW were > 0.05 showing that scenario 1 scores obtained for SA, TW and TM were not influenced by anaesthetic nurse attendance to previous NTSW. On the other hand, the scores for TM, SA and TW were all influenced by PS and exposure to MTPM as seen from the corresponding p-values (Table III B).

TABLE III A
CORRESPONDING MANN-WHITNEY P-VALUES FOR THE DIFFERENT VARIABLES IN SCENARIO 1 FOR ANAESTHETISTS

Scenario 1 - Anaesthetists		TM	TW	SA	DM
PS	P-value	0.345	0.347	0.743	0.936
Previous NTSW	P-value	0.316	0.851	0.615	0.436
Exposure to MTPM	P-value	0.748	0.502	0.538	0.501

TABLE III B
CORRESPONDING MANN-WHITNEY P-VALUES FOR THE DIFFERENT VARIABLES IN SCENARIO 1 FOR ANAESTHETIC NURSES

Scenario 1 - Anaesthetic Nurses		SA	TW/C	TM
PS	P-value	0.007	0.010	0.036
Previous NTSW	P-value	0.523	0.675	0.920
Exposure to MTPM	P-value	0.015	0.005	0.039

The p-values for the scores achieved in TM, TW, SA, DM in simulations during scenarios 1 & 2, and scenarios 1 & 3, were assessed for significant improvement. As none of the scores' differences were normally distributed, the Wilcoxon signed test was used. Since the test conducted were one-tailed tests, the p-values were divided by 2. The resulting anaesthetist p-values were: 0.0035, 0.0005, 0.002, 0.0005, 0.0015, 0.0005, 0.0005, 0.0005, indicating a significant improvement in all NTS scores between both scenarios 1 & 2 and 1 & 3. In the case of the anaesthetic nurses' group, the resulting p-values were: 0, 0, 0.0095, 0, 0, 0, showing significant improvement in score in all NTS between scenarios 1 & 2, and 1 & 3.

Another point of interest was to analyse whether the difference in scores in the NTS achieved between scenario 1 & 2; scenarios 1 & 3 was influenced by PS, previous NTSW, exposure to MTPM, group size and years of experience. Eight linear models with the score differences obtained in NTS were taken as response variables. Whilst PS, previous NTSW, exposure to MTPM, group size and years of experience were taken as explanatory variables.

For the anaesthetist group: previous NTSW, exposure to MTPM, group size and years of experience, did not display influence on the scores' differences achieved. An influence of PS was detected in the scores' differences for TM between scenarios 1 & 2 ($P = 0.035$). Yet, this subgroup (5 anaesthetists) was considered a small sample size, making this observation unreliable. The anaesthetic nursing group size did not influence any of the resulting differences in the scores achieved for NTS. Nevertheless, PS was found to influence the difference in scores achieved for TW between scenario 1 & 2 ($P = 0.018$), the difference in scores achieved for TW from scenario 1 & 3 ($P = 0.001$), and the difference in scores achieved for TM from scenario 1 & 3 ($P = 0.013$).

Previous NTSW influenced difference in anaesthetic nurses' scores achieved for TW from scenario 1 & 3 ($P = 0.012$), and the difference in scores achieved for TM from scenario 1 & 3 ($P = 0.044$). Moreover, anaesthetic nurses' years of experience influenced SA scores difference achieved between scenarios 1 & 2 ($P = 0.036$), and exposure to MTPM influenced TW scores difference achieved between scenarios 1 & 3 ($P = 0$). The difference in scores achieved for scenarios 1 & 2 for TM and the difference in scores achieved for scenarios 1 & 3 for SA were not affected by any of the explanatory variables considered in the linear models.

IV. DISCUSSION

Evidence suggests that multidisciplinary SBT remains infrequent, despite it being the norm in clinical care [16]. This study revealed that less than half of the anaesthetic nurses (48.8%) were exposed to PS. Lack of opportunities, time and financial issues were cited as the most common barriers to SBT exposure [17]. Other barriers include stress, fear of judgement, unfamiliarity with equipment and videotaping [18]. Nonetheless, the exposure to PS for the anaesthetists was 85.3%. Highlighting that local SBT is predisposed towards anaesthetists. Involving more anaesthetic nurses to SBT programmes can remedy the situation. However, additional insight into overall educational objectives, and their professional concerns, is required before the launch of multidisciplinary team training [18].

Previous studies on multidisciplinary crisis team simulation training have demonstrated that participants completed more key tasks with successive simulation sessions, translating into improved 'patient' and clinical potential outcomes [16]. A pre-study NTSW conducted at MDH was well-attended by both anaesthetic nurses and anaesthetists. This explains the better percentage for NTSW in the nursing group (63.4%) when compared to PS. As expected, exposure to MTPM was higher for more experienced participants, as local safe theatre practices mandate that the most challenging patients, are handled by personnel who are appropriately trained and more experienced [19], [20].

Scenario 2 being a CICO scenario required coordination of tasks, adequate planning, preparation, prioritizing & identifying, and utilizing resources, were key to determine the solution expeditiously; as hypoxia would have ensued resulting in secondary brain injury. Serious airway management complications during anaesthesia cannot be avoided by adoption and guidelines execution alone [21]. Group dynamics displayed an influence too. While homogenous small groups displayed better performance in "production type situations", larger more heterogeneous groups exhibited broader problem-solving creativity, at the expense of more probable conflict [22], [23]. DM is impaired by cognitive overload and task fixation. CICO guidelines are based on the 'stop and think' concept, providing required instructions to reduce risk [24]. CICO is a rare event; therefore, rehearsal can only be achieved through simulation, providing great NTS coaching opportunities [21], [24]. Furthermore, expertise affects TM through better prioritization, planning, and SA [25]. Additionally, years of experience for anaesthetic nurses influenced the SA scores difference between scenario 1 & 2.

SBT reinforces understanding across disciplines and facilitates communication, leadership, cooperation, TW, which are fundamental in trauma resuscitation [26], [27]. The opportunity of having 3 scenarios followed by a team debrief facilitated the possibility of hindsight learning without endangering patients [26]. Furthermore, exposure to clinically infrequent scenarios provided learning opportunities in a safe and controlled setting [27]. Successful training has been linked to improved clinical outcome and higher quality MTPM [28]. However, skill retention after training completion remains a challenge [29]. One-off training sessions are not as effective. Although difficult to accomplish, intensive regular training

interventions are required to sustain a cumulative effect [30]. SBT challenges include: costs, personnel, time off-clinical duties, and inter-departmental planning [31]. Moreover, TM, SA and TW/C for scenario 1 were all influenced by PS and exposure to MTPM. Team performance improved with SBT and clinical experience (higher exposure to MTPM): improvements were demonstrated in critical decisions, TW, functional outputs and efficiency [27], [32], [33].

V. Limitations

The main limitations of this study were:

- the small number of participants,
- the study's geographical location, and
- the participants' exclusivity to the anaesthetic specialty.

The studied sample was representative of the local population of anaesthetists and nurses, currently employed at MDH. The small sample size and the fact that participants were working colleagues reduce the power of the study. Moreover, both the geographical location and the exclusion of other medical specialties may be misrepresentative of the ongoing practices in international hospitals. Further studies using larger participant numbers, diverse specialties, and varied medical facilities, would produce a broader picture of operating theatre practices during major trauma management.

The conducted study was not designed to gauge the long-term impact of NTS effectiveness. Although the NTS rater of the study received training in NTS facilitation and assessment, it is thought that 2 behavioural performance raters would have improved performance assessment; however this was considered unfeasible [6]. Furthermore, the NTS rater was not blinded and video recording was not used to re-evaluate NTS performances. Major trauma management is highly variable by nature. Due to time limitations, the 3 scenarios were simulated on the same day. Yet, the simulations conducted did mimic potential scenarios and provided an adequate platform for skill-set assessment. Conducting the study during real-life cases, in an actual operating theatre was not feasible.

VI. Conclusion

In conclusion, SBT exhibited NTS improvement in both anaesthetists' and nurses' performances. Additionally, SBT facilitated communication, leadership, cooperation and TW, improved safety during MTPM, which is fundamental to trauma resuscitation. The cumulative effect of multidisciplinary simulation training provided an environment to rehearse uncommon crises and reinforced understanding across disciplines. Yet more studies are required to evaluate time frames between simulations and skill retention. Further research is warranted to ascertain the usefulness of NTS simulation training in the clinical environment and its impact on patient management.

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