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Comparison of Airway Ultrasound and Conventional Methods in Airway Management: Effectiveness and Temporal Efficiency in Traumatic Patients in Emergency Department

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ABSTRACT

Introduction: Effective airway management is critical in trauma care, particularly in the emergency department (ED), where rapid decisions impact outcomes. While conventional methods like auscultation and capnography are widely used for endotracheal tube (ETT) confirmation, their limitations highlight the need for Airway Ultrasound (AUS), offering real-time imaging and enhanced accuracy in trauma patients.

Method: This prospective, single-center study was conducted in the ED of a tertiary care hospital to compare AUS and standard clinical assessment (SCA) for confirming ETT placement during Rapid Sequence Intubation (RSI) in adult trauma patients. Patients were randomized into AUS or SCA groups. Primary outcomes included success rates, number of intubation attempts, and confirmation time and adverse events, including esophageal intubation and hypoxemia.

Result: The AUS arm showed higher overall success (100% vs. 96%) and first-attempt success rates (94% vs. 76%) and required fewer attempts (1.06 ± 0.2 vs. 1.22 ± 0.5). Time metrics significantly favored AUS, with faster intubation (8.9 vs. 13.1 seconds) and confirmation (45 vs. 91.4 seconds). Esophageal intubation was significantly less frequent with AUS (6% vs. 18%, $p = 0.042$).

Conclusion: AUS is a transformative tool in trauma airway management, improving visualization, accuracy, efficiency, and safety. With advancing technology, integrating AUS, standardized protocols, and training will solidify its role in trauma care, ensuring safer and more effective outcomes in emergency medicine.

Key Words: Airway Ultrasound (AUS), Airway Management, Trauma Patients, Emergency Department

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INTRODUCTION

Effective airway management is a vital component of trauma care, particularly in the fast-paced environment of the emergency department (ED), where time-critical decisions significantly impact patient outcomes.[1] Rapid Sequence Intubation (RSI) is the preferred method for securing the airway in trauma patients, but its success hinges on the accurate placement of the endotracheal tube (ETT).[2] Conventional methods, such as standard clinical assessment (SCA) with auscultation and waveform capnography, are widely used for ETT confirmation.[3] However, these techniques have limitations, including false positives and delays in detecting esophageal intubations, especially in high-stress trauma scenarios where precision is paramount.

Airway Ultrasound (AUS) has emerged as a promising adjunct in ED, offering real-time visualization and dynamic confirmation of ETT placement.[4] Unlike SCA, which relies on indirect markers, AUS provides direct imaging of laryngeal and esophageal anatomy, potentially reducing errors and expediting procedural efficiency. While previous studies have explored the use of AUS in general ED populations, limited research has focused on its efficacy specifically in trauma patients—who present unique challenges such as altered anatomy, cervical spine precautions, and hemodynamic instability.[5]

This randomized controlled study aims to address this gap by comparing AUS with conventional methods in adult trauma patients requiring emergent airway management. The study evaluates primary outcomes such as success rates, number of intubation attempts, and time to confirm ETT placement. Secondary outcomes include adverse events like esophageal intubation and hypoxemia. We hypothesize that AUS-guided intubation will not only improve success rates but also enhance temporal efficiency, offering a safer and more effective alternative to conventional techniques. By providing robust evidence, this study seeks to redefine airway management protocols, ultimately improving outcomes for critically injured patients in the ED.

MATERIALS AND METHODS

Study Design: This was a prospective, single-center study conducted to evaluate the integration of AUS in RSI for confirming ETT placement compared to conventional clinical methods, SCA in ED.

Study Settings: This non-blinded study was conducted over one year in a tertiary care ED fully equipped to manage trauma patients. All intubation procedures were performed by emergency physicians with a minimum of five years of experience in airway management and use of Point of care ultrasound in trauma. In the SCA arm, standard airway management tools were employed, including a Macintosh® curved laryngoscope (size 3 or 4 blades) and capnography for tube confirmation. The AUS-guided RSI group utilized a Sonosite® M-Turbo ultrasound machine with a 10–5 MHz linear probe for real-time visualization and guidance. Both groups used other standard equipment for intubation, such as the Sterimed® Intubating Stylet (SS 753) and Sterimed® cuffed endotracheal tubes (SMD 701 C, ISO 9001:2008).

Study Population: A total of 100 adult trauma patients requiring RSI for emergent airway management were included in the study.

Eligibility Criteria: Adults patients aged ≥18 years requiring RSI and trauma patients presenting to the ED requiring RSI for maintenance of airway were included in the study. Patients with cardiac arrest, pre-existing tracheal injury or open thoracic wounds, transfer-in patients with established ETT placement or pregnant patients (positive β-HCG test) were excluded from the study.

Study Protocol: All patients arriving to ED with trauma were managed by detailed primary survey. If patient required a definitive airway by rapid sequence intubation (RSI), they underwent pre-oxygenation with 100% oxygen via a bag-valve-mask for three minutes. Manual in-line neck stabilization (MILS) was applied for patients with suspected cervical spine injuries. RSI was performed using induction agents and neuromuscular blockers based on clinical indications and discretion of ED physician:

Premedication agents: Midazolam 0.1-0.3 mg//kg IV) or Lidocaine (1-1.5 mg/kg IV)
Induction agents: Etomidate (0.3-0.4 mg/kg IV) or Ketamine (1.5-2 mg/kg IV in case ofcardiac instability).
Neuromuscular blockers: Succinylcholine (1-2 mg/kg IV) or Rocuronium (0.6-1.2 mg/kg IV).

Then the participants were randomly assigned to one of two groups:

Group 1: AUS arm: Real-time ultrasound guidance, was used during laryngoscopy to visualize the endotracheal tube's passage and confirm correct placement through dynamic ultrasound assessment.[6]

Group 2: SCA arm: Intubation followed standard Advanced Trauma Life Support (ATLS) protocols, with tube placement confirmed by five-point auscultation and waveform capnography.[7]

Randomization: Patients were randomly assigned to either the AUS or SCA group using a computer-generated randomization sequence. A 1:1 allocation ratio was ensured, with allocation concealment achieved through sequentially numbered, sealed opaque envelopes.

Outcome Measures: The **primary outcomes** were the overall success rate, the number of attempts for successful intubation, and the time taken to confirm ETT placement. The **secondary outcomes** included time to intubation, time to adjust tube position, and the incidence of adverse events such as esophageal intubation and hypoxemia.

Ethical Considerations: The study was approved by the institutional ethics committee and conducted in compliance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants or their legal representatives prior to enrollment. Data were anonymized to maintain confidentiality.

Statistical Analysis: Descriptive statistics summarized participant demographics and baseline characteristics. The Chi-square test was used to compare success rates and adverse event frequencies between groups, with effect sizes reported using Cramer's V. Continuous variables, such as time metrics and the number of attempts, were analyzed using independent t-tests, with Cohen's d reported to indicate effect sizes. The influence of professional experience on intubation attempts and time was assessed using one-way ANOVA. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean age of participants was 34.5 ± 10.3 years, with no significant difference between the AUS arm (33.8 ± 9.9 years) and the CE arm (35.2 ± 10.7 years; p = 0.451). Gender distribution was similar, with 83% male participants (82% in the AUS arm and 84% in the CE arm; p = 0.781). The most common mechanism of trauma was road traffic accidents (71%), followed by falls (16%) with comparable distributions across the AUS and CE arms (p > 0.8 for all comparisons). (Table1)

The experience of emergency physician was similar between the AUS (8.8 ± 3.5 years) and CE (8.6 ± 3.3 years) arms, with no statistically significant difference. The overall success rate was 100% in the AUS arm and 96% in the CE arm.

Table 1: Demographic Characteristics of Patients

Characteristic	Overall (%) (n=100)	AUS Arm (%) (n=50)	CE Arm (%) (n=50)	P value
Age (mean years ± SD)	34.5 ± 10.3	33.8 ± 9.9	35.2 ± 10.7	0.451
Gender				
Male	83 (83)	41 (82)	42 (84)	0.781
Female	17 (17)	9 (18)	8 (16)	-
Mechanism of Trauma				
Road Traffic Accident	71 (71)	36 (72)	35 (70)	0.821
Fall	16 (16)	8 (16)	8 (16)	-
Assault	13 (13)	6 (12)	7 (14)	-

Table 2: Comparison of Success Rates, Attempts, and Procedure

Metric	AUS Arm (n=50)	CE Arm (n=50)	Cramer's V / Cohen's d†	P Value
Experience (years)	8.8 ± 3.5	8.6 ± 3.3	0.06†	0.721
Overall Success Rate **(n, %)**	50 (100%)	48 (96%)	0.152	0.152
Attempts				
Number of Attempts	1.06 ± 0.2	1.22 ± 0.5	−0.38†	0.019
First Attempt Success	47 (94%)	38 (76%)	0.451	<0.001
Second Attempt Success	3 (6%)	8 (16%)	0.249	0.078
Third Attempt Success	0 (0%)	2 (4%)	0.178	0.155
Procedural Time (s, Mean ± SD)				
Time to Visualize Vocal Cords	4.5 ± 1.1	6.3 ± 1.8	−1.14†	<0.001
Time to Intubation	8.9 ± 2.4	13.1 ± 3.7	−1.33†	<0.001
Time to Adjust Tube Position	1.5 ± 0.4	3.2 ± 1.1	−1.95†	<0.001
Total Time to Confirmation	45.0 ± 7.8	91.4 ± 19.6	−2.98†	<0.001

Table 3: Comparison of Adverse Events

Adverse Event	AUS Arm n(n%)	CE Arm n(n%)	Relative Risk (95% CI)
Esophageal Intubation	3 (6)	9 (18)	0.33 (0.09–0.99)
Desaturation	6 (12)	10 (20)	0.60 (0.22–1.64)
Post-intubation Hypotension	4 (8)	9 (18)	0.44 (0.14–1.33)

Table 4: Experience Influencing Attempts

Experience Level (years)	Mean ± SD	95% CI for Mean Difference	Effect Size (Cohen's d)	P value
AUS Arm				
≤5	1.35 ± 0.5	0.12 to 1.14	0.62	0.03
5 -10	1.15 ± 0.4	-0.02 to 0.90	0.41	0.117
>10	1.05 ± 0.2	0.68 to 1.60	1.14	<0.001
CE Arm				
≤5	12.6 ± 3.4	1.25 to 3.50	0.85	0.004
5 -10	10.8 ± 2.8	-0.01 to 2.10	0.57	0.052
>10	8.9 ± 2.1	1.75 to 3.40	1.25	<0.001

The mean number of attempts in the AUS arm (1.06 ± 0.2) compared to the CE arm (1.22 ± 0.5). Similarly, first-attempt success was statistically significantly higher in the AUS arm (94%) than in the CE arm (76%). All time metrics showed statistically significant differences favoring the AUS arm. The mean time to visualize vocal cords (4.5 ± 1.1 vs. 6.3 ± 1.8 seconds), time to intubation (8.9 ± 2.4 vs. 13.1 ± 3.7 seconds), time to adjust tube position (1.5 ± 0.4 vs. 3.2 ± 1.1 seconds), and total time to confirmation (45.0 ± 7.8 vs. 91.4 ± 19.6 seconds) were all statistically significantly shorter in the AUS arm. (Table 2)

Esophageal intubation occurred significantly less frequently in the AUS arm (6%) compared to the CE arm (18%) ($p = 0.042$). There were no statistically significant differences between the AUS and CE arms in the rates of desaturation (12% vs. 20%) and post-intubation hypotension (8% vs. 18%). (Table 3)

Emergency physicians with ≤5 years of experience had the highest mean attempts (1.35 ± 0.5) and the longest total intubation time (12.6 ± 3.4 seconds). Compared to this group, those with >10 years of experience demonstrated significantly fewer attempts (1.05 ± 0.2, $p < 0.001$) and shorter intubation times (8.9 ± 2.1 seconds, $p < 0.001$). Intermediate experience (5–10 years) showed moderate values (1.15 ± 0.4 attempts, 10.8 ± 2.8 seconds) but without statistical significance compared to the ≤5-year group ($p = 0.117$ for attempts and $p = 0.052$ for time). (Table 4)

DISCUSSION

The integration of AUS into airway management protocols represents a transformative advancement in the emergency care of trauma patients. This study reaffirms the significant advantages of AUS over conventional methods, particularly in achieving higher first-attempt success rates and reducing the time required for confirming ETT placement. We found a high first-attempt success rate compared to conventional methods group, in line with, Wang et al. who reported a first-pass success rate of 90% for AUS assisted intubation.[8] A similar finding was also noted by Tian et al., in a systematic review who found a better AUS-assisted intubation resulted in fewer attempts compared to traditional methods, emphasizing that AUS underscores its efficacy in minimizing the need for repeated attempts, which is crucial in trauma patients who often have complex airway challenges.[9] The reduction in attempts is also vital for avoiding complications such as aspiration, and hypoxemia.

Additionally, the expedited confirmation times observed with AUS, as highlighted by Neethirajan et al. (21.63 ± 7.38 seconds for ultrasound versus 40.62 ± 7.93 seconds for capnography), closely mirror our findings and further underscore the tool's crucial role in enhancing procedural efficiency.[10] In high-pressure trauma settings, where every second counts, such reductions in confirmation times can be pivotal. AUS offers a distinct advantage by providing real-time, dynamic visualization of critical airway structures, such as the cricothyroid membrane and vocal cords.[4] This ability to directly observe anatomical landmarks is especially valuable in trauma patients, where conventional methods—such as auscultation and waveform capnography—can be compromised. Factors like anatomical distortions, swelling, or the presence of environmental noise often reduce the reliability of these traditional techniques. In contrast, the real-time imaging capability of AUS enables emergency physicians to make more precise and informed clinical decisions by visualizing the airway in its entirety.[11] Moreover, AUS's ability to confirm proper endotracheal tube (ETT) placement immediately after intubation ensures the rapid detection of potential misplacements, significantly reducing the likelihood of complications such as esophageal intubation or inadequate ventilation.[12] This enhanced accuracy not only improves patient safety but also optimizes procedural outcomes in critical care environments.

Traditional clinical assessments often suffer from limited sensitivity and specificity, relying on criteria that may not fully account for anatomical variability. AUS addresses these limitations by providing objective ultrasound-based metrics, such as skin-to-epiglottis distance and tongue thickness, which are more reliable indicators of airway difficulty.[13] Integrating these parameters into existing airway management algorithms allows for a more precise prediction of challenging intubations, enabling clinicians to prepare adequately and tailor their approach. This individualized strategy is especially critical for high-risk patients, such as those with hemodynamic instability or pre-existing anatomical abnormalities, where standard techniques may be insufficient.

The role of ultrasound extends beyond airway management to include broader applications in trauma care. Its versatility allows for simultaneous assessments of other critical areas, such as internal bleeding through Focused Assessment with Sonography for Trauma (FAST) exams, enhancing its value in comprehensive emergency protocols.[14] The portability of modern ultrasound devices further expands their utility to prehospital environments, enabling rapid assessments and interventions in resource-constrained or field settings. This adaptability makes ultrasound an indispensable tool for emergency physicians, particularly in scenarios requiring immediate, multi-dimensional evaluations.

Despite its numerous advantages, the successful integration of AUS into airway management protocols requires adequate training and proficiency among healthcare providers. Studies have consistently shown that operators with advanced AUS training achieve higher success rates and shorter procedural times compared to their less experienced counterparts.[15] Incorporating standardized ultrasound education into airway management training programs will ensure that practitioners develop the necessary skills to use this technology effectively. Beyond improving individual competency, such training can foster adherence to standardized protocols, leading to better patient care outcomes. Gilbertson et al, findings underscore the potential for AUS to not only enhance clinical outcomes but also shape the future of medical education by equipping the next generation of emergency physicians with cutting-edge skills.[16]

Future advancements in AUS technology hold immense promise for further improving its integration into airway management. The development of artificial intelligence (AI)-assisted ultrasound systems could enhance diagnostic accuracy by providing real-time feedback and pattern recognition, even for less experienced operators.[17] Augmented reality (AR) overlays integrated with ultrasound imaging could offer intuitive visualizations of anatomical landmarks, simplifying complex procedures. Additionally, portable, AI-enabled handheld ultrasound devices have the potential to democratize access to AUS, particularly in resource-limited settings. Smart endotracheal tubes equipped with integrated sensors for real-time confirmation of tube placement could complement AUS, further enhancing safety and efficiency.[18]

CONCLUSION

The findings of this study, combined with the growing body of literature, underscore the transformative impact of AUS on airway management in trauma care. By enhancing visualization, improving predictive accuracy, reducing procedural times, and minimizing adverse events, AUS represents a significant step forward in emergency medicine. As technology continues to evolve, the integration of advanced tools, robust training programs, and standardized protocols will solidify AUS as a cornerstone of modern trauma care. The future of AUS in airway management is bright, promising safer and more efficient outcomes for patients and advancing the field of emergency medicine to new heights.

Approval of Ethical committee: The Institutional Ethical Committee approved the study, with Reg No: ECR/662/Inst/KL/2022/RR-16.

Authors Contributions: VK - Study conception and manuscript preparation; **PR**- Data analysis and interpretation and manuscript preparation; **SC**- study design and Data analysis, **AJ**- date collection and Study conception.

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