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REVIEW

Unrecognised oesophageal intubation: a review

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Abstract

Oesophageal intubation is dangerous if not promptly identified and managed. It often results from human error and inadequate education. An advanced technologies can mitigate the risk of this serious complication and enhance patient safety. This narrative review evaluated contemporary publications concerning unrecognised oesophageal intubation in the surgical theatre. PubMed, Scopus, and the Cochrane Library were searched for relevant articles published from 2010 to 2025, excluding non-English manuscripts, case reports, and studies lacking pertinent data. The effectiveness of capnography, video laryngoscopy, and simulation training was analysed to determine intubation rates across various clinical settings. The narrative review indicated that the rates of unrecognised oesophageal intubation range from 2.9% to 16.7%, and are associated with increased mortality. The implementation of video laryngoscopy reduced these rates by approximately 50%, while simulation training improved first-attempt intubation success. The findings underscore the necessity of incorporating advanced monitoring systems and simulation-based training into anaesthesia protocols to reduce the risks associated with overlooked oesophageal intubation. This fosters a safety-oriented culture and utilises technological innovations to significantly improve patient outcomes and decrease the incidence of this severe complication.

Keywords

Oesophageal intubation; Human factors; Monitoring; Patient safety; Simulation; Training

1. Introduction

This review aims to consolidate evidence on unrecognised oesophageal intubation in anaesthesia, assessing the prevalence, associated risks, and the efficacy of advanced monitoring technologies, while emphasising the role of video laryngoscopy, capnography, and simulation training in enhancing patient safety and anaesthesia practices.

Unexpected oesophageal intubation during anaesthesia constitutes a critical complication that jeopardises patient safety, as demonstrated by various case studies and reviews. This issue frequently stems from human error and affects patients regardless of the practitioner's skill level, thus remaining a significant concern despite advancements in monitoring and airway management techniques [1]. The prevalence of undetected oesophageal intubation rates, ranging from 2.9% to 16.7%, highlights a critical concern in airway management, which necessitates comprehensive training and proficiency in tube placement verification. Structured programmes, such as simulation and refresher courses, are vital for enhancing clinician competence and ensuring patient safety against such errors [1–3]. Unrecognised oesophageal intubation persists as a considerable issue across various medical disciplines, particularly in anaesthesia and emergency medicine, with documented occurrences ranging from 0.3% to 3% within anaesthesia and escalating to 6.7% in emergency contexts. Factors influencing these statistics include the urgency of cases, the level of clinician expertise, and the quality of monitoring practices, with emergency physicians often lacking the sophisticated monitoring instruments typically accessible to anaesthesiologists [1, 4].

Assessing the potential for difficult tracheal intubation before surgical interventions is essential for patient safety and optimising anaesthesia. Vital tools include the Modified Mallampati Test (MMT), Thyromental Distance (TMD), and Upper Lip Bite Test (ULBT), with the MMT providing a foundational assessment of oropharyngeal anatomy, further refined by the Thyromental Height Test, noted for its superior sensitivity and specificity in predicting intubation challenges [5].

The predictive validity of the Mallampati score is limited, as shown by its less-than-ideal sensitivity and specificity for difficult intubations, with studies reporting a sensitivity of 82.9% and specificity of 79.1% for challenging laryngoscopy, and a sensitivity of 88.9% and specificity of 87% for difficult intubation [6]. The El-Ganzouri Risk Index, which integrates numerous variables, including MMT, TMD, and cervical mobility, yields a thorough risk evaluation [7]. Research indicates that no single test can consistently predict difficult intubation; however, the unification of tests, such as MMT with TMD or ULBT, enhances diagnostic precision. The ULBT, specifi-

cally, has been recognised as a potent indicator with substantial specificity [8]. Despite these tests, many airway complications remain unforeseen, emphasising the necessity for anaesthesiologists to be equipped for unexpected scenarios. Integrating sophisticated imaging technologies, including ultrasound and endoscopy, offers hope for improving preoperative airway evaluations, yet further exploration is needed to refine these approaches [9]. Continuous waveform capnography is the optimal standard for verifying tube placement; however, its inadequate utilisation significantly delays the identification of oesophageal intubation. Research suggests that reliance solely on clinical indicators, such as auscultation or observation of chest movement, is insufficient and may lead to misdiagnosis and dire consequences. Enhanced training, the incorporation of video laryngoscopy, and strict adherence to evidence-based protocols are crucial methodologies to enhance patient safety [4].

Narrative reviews synthesise knowledge, identify gaps, and advocate for best practices like continuous waveform capnography and video laryngoscopy to enhance airway management and mitigate associated risks [4, 10].

The campaign and guidelines of the Royal College of Anesthetists (2018) emphasise the importance of capnography, video laryngoscopy, and oxygen saturation monitoring to mitigate these risks [3]. Nonetheless, oesophageal intubation persists in 5.5% of critically ill patients and may escalate to as high as 17% in out-of-hospital scenarios, suggesting possible underreporting of such events [10]. Human factors, including poor communication and hierarchical issues, exacerbate this problem, necessitating a focus on education, teamwork, and simulation training [1]. Although video laryngoscopy and supraglottic airways have diminished occurrence rates, adopting comprehensive approaches, including mandatory airway management education and extensive capnography implementation, is crucial for improving patient safety [1].

Research on monitoring technologies in intubation safety is critical for reducing airway complications, with considerable advancements in airway management evidenced by the advent of capnography in the 1990s, alongside innovations like video laryngoscopy and collaborative airway response teams [1, 11]. The practical relevance of this domain is accentuated by empirical data indicating that unrecognised oesophageal intubation continues to be a predominant contributor to anaesthesia-related fatalities and neurological injuries on a global scale. On a worldwide scale, the absence of access to capnography in low- and middle-income countries exacerbates the elevated perioperative mortality rates, thus highlighting the pressing necessity for equitable distribution of monitoring technologies [12, 13].

2. Methodology

2.1 Literature search strategy

This spanned multiple databases, including PubMed, Scopus, and the Cochrane Library. The research utilised terms including oesophageal intubation, capnography, video laryngoscopy, simulation training, and patient safety. The research featured the most up-to-date articles issued from 2010 through 2025. The paper incorporated studies on adult patients undergoing anaesthesia, particularly those addressing unrecognised oesophageal intubation, monitoring technologies, and training methodologies. The review omitted publications not in the English language, case reports, animal studies, and articles lacking relevant information regarding the desired outcomes.

2.2 Data extraction

Pertinent studies were reviewed and critical data extracted. This included prevalence rates of unrecognised oesophageal intubation, outcomes associated with diverse monitoring technologies, and results from simulation training programmes.

2.3 Critical appraisal

The included studies were evaluated to ensure transparency throughout the literature search and selection process. We recognised limitations and presented a nuanced perspective of the evidence, including any conflicting findings.

2.4 Synthesis of findings

The findings from the selected studies provided an overview of the current knowledge concerning unrecognised oesophageal intubation and the role of advanced technologies in risk mitigation.

3. Prevalence and impact

Unrecognised oesophageal intubation significantly threatens patient safety, as evidenced by the 4th National Audit Project (NAP4) in the UK, which recorded nine cases resulting in six fatalities and one neurological impairment [1]. An analysis from Australia and New Zealand revealed 109 instances of oesophageal intubation between 2009 and 2022, with 43% causing oxygen desaturation, thus highlighting the widespread nature of this concern [14]. A study in New South Wales reported a 3.1% prevalence of this issue among transported intubated patients, indicating its relevance in hospital and prehospital settings [15]. The promotion of video laryngoscopy and waveform capnography is essential for reducing these incidents and improving airway management practices globally, particularly in regions like Saudi Arabia, where training gaps exist [16, 17].

4. Training gaps

The educational framework surrounding anaesthesia, particularly regarding airway management in the Kingdom of Saudi Arabia, is intricately influenced by both global best practices and specific strategic initiatives established at the national level. In response to the challenges imposed by the COVID-19 pandemic, the Saudi Anesthesia Society has taken significant steps to formulate comprehensive guidelines that prioritise structured educational training, recognising the urgent need for improvement in this vital area of medical education [16]. Nevertheless, a critical examination reveals that existing training programmes frequently fall short of equipping practitioners with the essential skills required to promptly identify and address the severe complications associated with unrecognised

oesophageal intubation. This situation undeniably endangers patient safety. This alarming shortcoming is further compounded by the prevalence of human errors that continue to occur within clinical practice, thereby underlining the imperative for the development of focused training initiatives that not only enhance technical skills, but also foster effective communication and collaborative teamwork abilities among healthcare professionals [1]. By methodically pinpointing and addressing these educational disparities, we can significantly enhance the quality of training offered, ultimately fostering greater proficiency in detecting and effectively addressing potential missteps in intubation techniques.

5. Key findings of the review

Table 1 (Ref. [1, 10, 14, 18]) highlights significant regional and contextual variations in unrecognized esophageal intubation, raising serious patient safety concerns. In some regions, a notable percentage of incidents lead to patient desaturation. Emergency settings exhibit higher rates due to urgency and monitoring challenges. Alarmingly, out-of-hospital scenarios show a concerning incidence, underscoring the urgent need for improved airway management practices across various healthcare environments.

Table 2 (Ref. [1, 13, 19–22]) illustrates the importance of monitoring technologies in reducing the hazards of unrecognised oesophageal intubation. Continuous waveform capnography is deemed the gold standard for tube placement verification, offering real-time monitoring despite specific constraints. Video laryngoscopy has significantly improved first-attempt intubation success rates, particularly in intricate cases. Concurrently, fibreoptic bronchoscopy is acknowledged for its high sensitivity and specificity in challenging airway scenarios, underscoring the necessity of integrating these technologies into routine practices to enhance patient safety during intubation [19].

6. Emerging technology

6.1 Simulation-based training

Simulation-driven education has emerged as a crucial strategy for improving first-attempt intubation success rates, particularly in high-pressure environments, such as intensive care units (ICUs). Evidence suggests that incorporating simulation curricula alongside airway training can markedly decrease the occurrences of oesophageal intubation from 5% to 1% [23]. This educational framework allows healthcare professionals to practice in a supervised environment, reducing the hazards connected to real patient encounters [24]. Moreover, research indicates that simulation enhances compliance with established guidelines, bolsters decision-making capabilities, and shortens the time required to commence critical procedures, such as cricothyroidotomy [25]. The success of simulation training lies in its ability to engage learners, thus boosting skill retention and reducing medical mishaps [6]. Ultimately, the fusion of simulation-based education and airway registries provides a crucial blueprint for enhancing patient safety and optimising intubation outcomes [26].

6.2 Airway devices

The implementation of video laryngoscopy (VL) has been empirically demonstrated to markedly enhance the success rates of tracheal intubation compared with traditional direct laryngoscopy, especially in the complex clinical situations encountered in emergency departments and ICUs. The device trial revealed that VL attained a first-attempt success rate of 85.1% in contrast to 70.8% for direct laryngoscopy, emphasising a notable absolute risk difference of 14.3% in favour of VL [20]. Furthermore, systematic reviews indicate that VL not only elevates visualisation, but also reduces the occurrence of unnoticed oesophageal intubation, with a documented risk reduction of 58% [27]. Additionally, VL promotes improved pedagogical approaches and collaborative practice due to its shared visual capabilities, rendering it a

TABLE 1. Incidence of undetected oesophageal intubation in some countries.

Citations	Region	Prevalence Rate (%)	Notes	Indications for Intubation
[1]	United Kingdom	2.9–16.7%	Based on the NAP4 audit, significant patient safety concerns.	General anaesthesia, airway protection
[14]	Australia and New Zealand	3.1%	109 cases reported from 2009 to 2022, 43% caused desaturation.	Emergency intubation, critical care
[10]	Emergency Settings	Up to 6.7%	Higher rates due to urgency and lack of monitoring tools.	Trauma, respiratory distress
[10]	Critically Ill Patients	5.5%	Ongoing issue despite improved practices.	Severe respiratory failure
[10]	Out-of-Hospital Scenarios	Up to 17%	Suggests possible underreporting.	Cardiopulmonary resuscitation
[18]	India	4.2%	Ultrasound is the fastest and most reliable method for confirming ETT placement by novice residents.	Elective intubations for general anesthesia

NAP4: the 4th National Audit Project.

TABLE 2. Efficacy analysis of various monitoring technologies.

Citations	Monitoring Technology	Efficacy	Notes	Interpretation
[1]	Continuous Waveform Capnography	Optimal standard for verifying tube placement	Provides real-time monitoring but has limitations.	Essential for confirming tube placement. Underuse can lead to serious errors.
[20]	Video Laryngoscopy	Increases first-attempt success rate	Preferred for complex situations.	Enhances clinician confidence.
[13]	Clinical Indicators (Auscultation, Chest Movement)	Insufficient alone, must be combined with advanced technologies	Important in multimodal evaluation.	Should be used as part of a comprehensive assessment.
[19]	Fiberoptic Bronchoscopy	High sensitivity and specificity	Best used in challenging airway scenarios.	Critical for a difficult airway.
[21, 22]	AI-Driven Detection Systems	High precision with promising results	Represents a future direction.	Potential to revolutionise intubation verification, requires further validation.

preferred instrument for novice practitioners [28]. Despite some inconsistent outcomes in prehospital contexts, the cumulative evidence advocates for routinely implementing VL as a primary airway management strategy to bolster patient safety and clinical outcomes.

6.3 Monitoring technologies

Continuous waveform capnography acts as a fundamental device for verifying the appropriate placement of endotracheal tubes (ETT). This modality offers immediate physiological data, facilitating the continuous observation of carbon dioxide concentrations throughout the process of ventilation. Such technological advances contribute significantly to the verification of correct tube positioning within the trachea, as it identifies exhaled carbon dioxide, which would be absent in instances where the tube is erroneously situated within the esophagus [1].

Capnography is an essential monitoring tool, yet its effectiveness can be diminished by overly deep tube insertion or considerable secretions. Such factors may hinder precise measurements and underscore the necessity for a thorough validation methodology [14].

To augment the reliability of verifying endotracheal tube placement, it is essential to integrate capnography with supplementary clinical indicators, as chest movement observation and breath sound auscultation yield critical insights into ventilation efficacy, while anatomical verification methods, like fiberoptic bronchoscopy and ultrasound, notably enhance assessment accuracy. In this context, ultrasonography demonstrating complete sensitivity and specificity in confirming tube placement, thus outperforming conventional clinical techniques [15].

6.4 Technological solutions

Innovative technologies are markedly improving patient safety in intubation by enhancing the identification and mitigation of oesophageal intubation risks, with capnography serving as a vital instrument for real-time monitoring of exhaled carbon dioxide to validate tracheal tube placement. However, the limitations of capnography, including potential false positives, necessitate the use of adjunctive technologies [3, 19]. Emerging technologies, particularly AI-driven detection systems, present significant advancements; for example, neural networks have been engineered to differentiate tracheal from oesophageal intubation by scrutinising flow and pressure waveforms, thereby exhibiting considerable precision in the early identification of oesophageal intubation [21]. Furthermore, artificial intelligence systems that employ image processing techniques during the intubation process have demonstrated an unequivocal success rate of 100% in validating appropriate tube positioning by recognising anatomical references such as the carina. The consensus guidelines recommend a coordinated approach, combining these technologies with training in human factors to minimise cognitive biases and improve team performance in stressful situations [10]. These advancements collectively aim to enhance patient safety by ensuring accurate and timely detection of oesophageal intubation, thereby reducing associated risks and improving clinical outcomes.

6.5 Overview of existing monitoring technologies

Emerging technologies, including implantable sensors and optical detection systems, substantially augment the oversight of oesophageal intubation and other pivotal medical procedures [29].

Integrating these breakthroughs alongside data management capabilities and the Internet of Things (IoT) significantly enhances the reliability and safety of healthcare devices by delivering instantaneous, accurate observations and urgent alerts to emergency personnel [30]. Incorporating these systems into healthcare methodologies revolutionises patient care by facilitating continuous surveillance and proactive clinical interventions. These systems possess the proficiency to supply constant, immediate data for supervising critical scenarios, such as oesophageal intubation, thereby enhancing patient

safety and therapeutic outcomes [31].

7. Limitations of current technology in preventing oesophageal intubation

Despite the progress achieved in monitoring technologies, the obstacles associated with averting undetected oesophageal intubation continue to be considerable. A principal concern is the inconsistent application and interpretation of continuous waveform capnography, further complicated by human factors, including cognitive biases and lapses in communication [1, 32]. Although capnography is considered the benchmark for validating tracheal tube placement, its efficacy may be compromised by erroneous interpretations, particularly in contexts where end-tidal CO_2 detection does not assure accurate placement [13, 19]. Clinical indicators such as auscultation and chest wall movement, while inadequate when considered in isolation, remain crucial elements of a multimodal assessment framework [1, 13]. The implementation of an integrative strategy that combines these clinical indicators with cutting-edge monitoring technologies, including video laryngoscopy and capnography, is imperative for enhancing patient safety and mitigating the incidence of this critical complication [1, 13]. In order to enhance safety protocols during the process of intubation within the dominion of anaesthesia, it is imperative to join advanced monitoring technologies with thorough training methodologies. For example, multiparameter and cerebral function monitors facilitate instantaneous assessments, thereby substantially augmenting patient safety throughout the perioperative continuum [33]. The implementation of video laryngoscopy has likewise contributed to the efficacy and safety of tracheal intubation, thereby effectively diminishing the incidence of intricate airway complications and the necessity for urgent interventions [34]. The advancement of intelligent monitoring systems that amalgamate comprehensive physiological data enhances patient care through improved diagnostic and therapeutic interventions. However, issues concerning data management and cognitive overload remain [35] while technologies like pulse oximetry and capnography have significantly decreased anaesthetic-related morbidity and mortality by facilitating the early identification of adverse events, such as oesophageal intubation [36]. Along with technological advancements, promoting a strong safety culture and effective teamwork among anesthesia professionals is crucial, given the potentially serious consequences of errors. Research highlights that creating an environment that encourages error reporting and learning from mistakes is vital for improving patient safety. The application of checklists, compliance with standardized protocols, and involvement in immersive simulation training have shown effectiveness in decreasing medication errors and improving clinical results [37]. The concept of psychological safety, which promotes the reporting of errors by team members without the fear of negative consequences, is pivotal for the establishment of a safety-oriented culture [38]. The Helsinki Declaration concerning patient safety in anaesthesiology further accentuates the significance of organizational modifications and the reporting of critical incidents to avert adverse outcomes [39]. In summation, collaboration among anaesthesia professionals, strengthened by ongoing educational initiatives and technological innovations, is vital for diminishing risks, such as undetected oesophageal intubation, thereby enhancing patient outcomes [40].

8. Cultural factors and team dynamics

A vigorous safety culture and proficient collaboration are essential in the anaesthesia domain, where the repercussions of errors can be significantly detrimental. Empirical studies stress that cultivating an atmosphere that promotes error documentation and the assimilation of lessons from missteps is fundamental for enhancing patient safety. Adopting checklists, following standardised protocols, and undergoing immersive simulation training have proven notably effective in decreasing medication mistakes and improving clinical results [37]. Moreover, the principle of psychological safety, which empowers team members to disclose errors without fear of repercussions, is indispensable for fostering a safety-oriented culture [38].

The Helsinki Declaration on patient safety in anaesthesiology accentuates the significance of organisational modifications and the reporting of critical incidents to avert adverse occurrences [39].

In summation, collaboration among anaesthesia professionals, strengthened by ongoing educational initiatives and technological innovations, is vital for diminishing risks, such as undetected oesophageal intubation, thereby enhancing patient outcomes [40].

9. Regulatory guidelines

The regulatory frameworks governing airway management emphasise the imperative for uniform clinical protocols to reduce errors, positing that advanced technologies, such as waveform capnography and video laryngoscopy, serve as auxiliary instruments rather than primary methodologies for error mitigation. These advanced modalities augment the verification of tracheal tube positioning when utilised in conjunction with clinical indicators and anatomical assessments, as illuminated by up-to-date research advocating for an integrative approach to airway management [19, 41]. The continual professional development of practitioners is paramount for maintaining awareness of advancements, including fibreoptic bronchoscopy and ultrasound, which are essential components of contemporary airway management paradigms [42]. Additionally, incorporating evidence-based protocols and persistent educational initiatives cultivates the provision of high-calibre care, thereby equipping healthcare professionals to adapt to progressive technologies and enhance patient safety during critical medical interventions [43].

10. Human factors and continuous professional development

The influence of Human Factors on Patient Safety is significant within anesthesia, requiring strong communication strategies to decrease incidents of errors, such as unnoticed esophageal intubation. A culture that empowers team members to voice concerns is critical for error identification. At the same time,

regular teamwork and communication training can foster collaboration and enhance patient safety [25]. Capnography, while the standard for verifying tracheal tube placement, can be less effective due to misinterpretations, especially when end-tidal CO_2 detection does not guarantee accurate placement [19].

Lifelong education within the field of anaesthesia practice is crucial for ensuring that practitioners remain informed about innovations, including technologies detecting oesophageal intubation, which are essential for enhancing patient safety and improving clinical outcomes. This ongoing educational endeavour constitutes a professional responsibility and a statutory obligation in numerous jurisdictions, guaranteeing that healthcare professionals uphold their licensure and deliver care of superior quality. Applying innovative technologies and instructional strategies in anaesthesia, such as artificial intelligence and simulation-based education, highlights the importance of ongoing learning in adapting to the rapidly evolving healthcare environment [3, 33, 44].

11. Conclusions

To effectively manage the challenge posed by unrecognised oesophageal intubation, stakeholders require practical recommendations. Policymakers must mandate capnography in anaesthesia practices, especially in high-risk settings, and support affordable devices for resource-limited areas. Training programmes should include mandatory simulations on airway management, emphasising capnography and oesophageal intubation awareness, along with continued professional education on emerging technologies. Furthermore, healthcare organisations should promote a safety culture through open communication and cooperative teamwork, thereby improving monitoring practices with structured training. By implementing these comprehensive strategies, stakeholders can enhance training and technology integration in anaesthesia, thereby decreasing unrecognised oesophageal intubation rates and improving patient outcomes in diverse healthcare environments.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

HS—contributed to all the works; designed the research plan; conducted the research; analyzed the data; wrote the paper.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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