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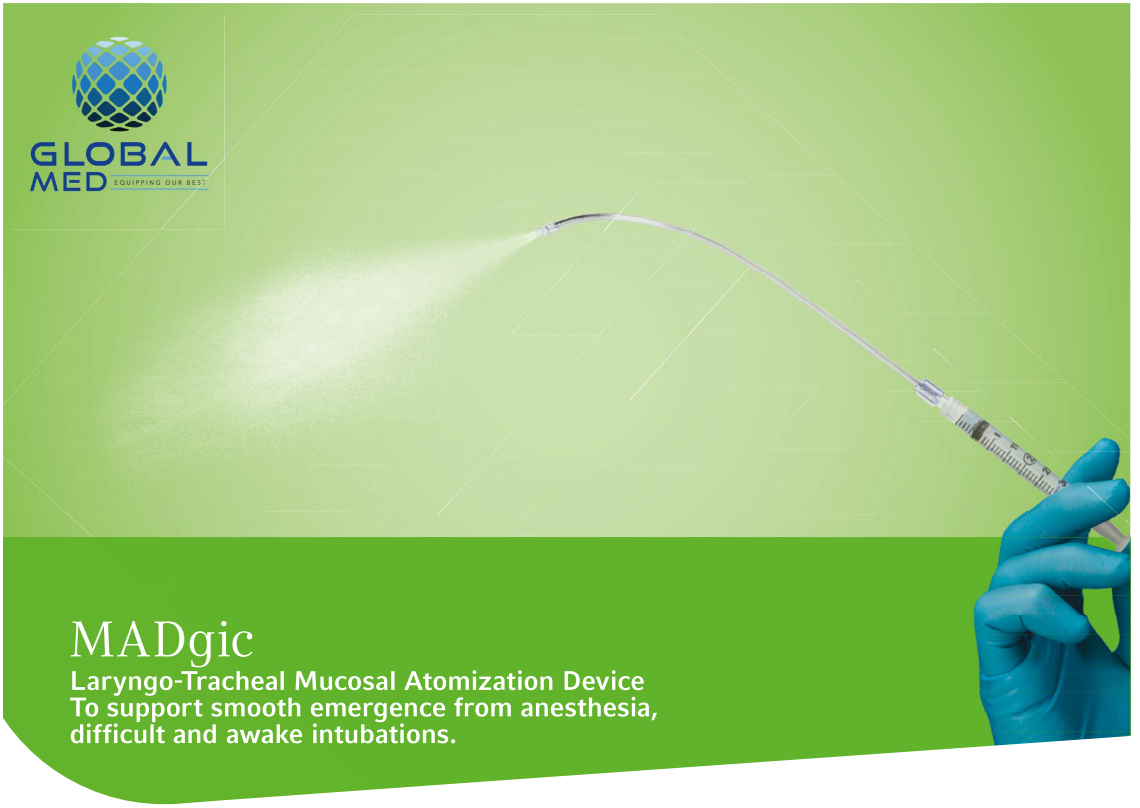

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Editorial
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Innovations in anaesthetic management of complex thoracic surgeries

Chaw Sook Hui, Noorjahan Haneem binti **Md Hashim**

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Recent advancements in anaesthetic and surgical approaches to thoracic procedures have underscored the importance of individualised care strategies. In this issue of MyJA, Nik Nabil *et al.* present an interesting case of non-intubated video-assisted thoracoscopic surgery (NiVATS) and its complications. This minimally invasive approach has seen advancements, particularly in anaesthesia techniques, patient selection, and postoperative outcomes.

This report emphasizes the growing preference for spontaneous ventilation techniques in thoracic surgeries, which eliminate the need for muscle relaxants and possibly hasten recovery. The authors managed a complex case requiring multiple oxygenation strategies, including high-flow oxygen, manual jet ventilation, and intermittent cross-field ventilation.

This case underscores 2 critical advancements in the field: (1) the feasibility of using high-flow oxygen and cross-field ventilation in maintaining oxygenation during NiVATS, and (2) the need for vigilant monitoring and management in cases of unexplained hypoxemia. These developments highlight a key shift in thoracic anaesthesia toward minimally invasive, patient-specific interventions, albeit with readiness for adaptive measures in emergent situations.

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Initially, NiVATS was limited to low-risk patients. However, recent studies show successful outcomes in moderate-risk patients, including those with mild-to-moderate pulmonary and cardiac comorbidities. Moreover, recent case reports document the use of NiVATS in procedures like tracheal resection and lobectomy. NiVATS has been successfully adapted for surgeries requiring complex airway management by managing oxygenation using cross-field ventilation and high-flow oxygen.[1]

Regarding the clinical outcomes and benefits of NiVATS, a meta-analysis by Deng *et al.* suggested that NiVATS exhibited good effects in improving short-term outcomes and yielded significantly shorter in-operating room time and hospital stays, as well as a significantly lower rate of postoperative complications than intubated VATS under general anaesthesia.[2] Additionally, patients often report less postoperative pain, reduced opioid requirements, and improved quality of life after NiVATS, as muscle relaxants are avoided and diaphragmatic and respiratory muscle function is preserved.[3]

A propensity-matched retrospective study on 104 patients who underwent NiVATS and intubated video-assisted thoracoscopic surgery (IVATS) under general anaesthesia showed comparable surgical and anaesthesia outcomes in both groups, with no differences in desaturation and higher peak $ETCO_2$, shorter anaesthesia induction time, and bleeding in the NiVATS group.

Despite advances, hypoxemia remains a challenge in NiVATS, particularly with spontaneous one-lung ventilation. Standardised protocols and training programs for anaesthesiologists are crucial to ensure widespread adoption.[4] While short-term benefits are clear, more data are needed on long-term outcomes in NiVATS patients regarding their functional recovery, lung function, and recurrence rates in oncologic cases.

The case report reflects a broader trend in thoracic surgery and anaesthesia toward adaptive, minimally invasive strategies prioritising patient stability without sacrificing surgical efficacy. The refinement of NiVATS exemplifies a future where perioperative anaesthetic techniques can be tailored to the demands of complex thoracic cases. These developments pave the way for safer, more flexible anaesthetic and surgical interventions, essential for improving outcomes in high-risk patient populations. Continued research and case reporting in these areas are essential to refine these techniques, ultimately expanding the toolkit available for anaesthesiologists and surgeons facing complex thoracic challenges.

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Editorial

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Multimodal analgesia as part of enhanced recovery after surgery in colorectal surgery

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Abstract

Introduction: Multimodal analgesia regime in enhanced recovery after surgery (ERAS) protocol is associated with fewer perioperative complications, shorter hospital stays, and reduced opioid dependence. Although ERAS strategies have been widely accepted and implemented in current practice, there is limited data regarding its application and outcomes in the Malaysian population, particularly in colorectal surgeries. Hence, this study was conducted to examine postoperative pain scores after implementing a multimodal analgesia regime as per ERAS anaesthesia protocol.

Methods: This is a retrospective study using data collection forms. Data were collected from the case notes of patients who underwent colorectal surgery complying with the ERAS anaesthesia protocol from January 2022 to December 2023. Pain score was assessed when the patient arrived at recovery bay, subsequently reassessed at 2 hours postoperative, 6 hours postoperative, 12 hours postoperative, 1 day postoperative and finally on postoperative day 2.

Results: A total of 139 samples were recruited in this retrospective study. The median postoperative pain scores at rest were consistently 0 from arrival at recovery bay to postoperative day 2. On the other hand, the median pain score upon movement

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was 1 (range 0–3) when patients reached the recovery bay, and persistently 3 during postoperative 2 hours, 6 hours, and 12 hours, after which the median pain score upon movement became 2 on postoperative day 1 and day 2.

Conclusions: Multimodal analgesia in line with the ERAS protocol in colorectal surgeries is feasible, safe and efficient.

Keywords: colorectal surgery, enhanced recovery after surgery, multimodal analgesia

Introduction

The enhanced recovery after surgery (ERAS) protocol is a protocol consisting of evidence-based items designed to reduce perioperative stress, maintain postoperative physiological function, and accelerate recovery after surgery. The multimodal approach has been shown to improve recovery, reduce morbidity, and shorten length of stay after colorectal surgery.[1]

One of the most important components of ERAS is multimodal analgesia. In a national survey, 80% of patients undergoing surgery report pain that is of moderate, severe, or extreme intensity in the first 2 weeks following surgery. Thus, postoperative pain management is a major concern for patients undergoing surgery.[2]

The opioid-based analgesia regime is the primary analgesia modality for many anaesthesiologists regardless of the type of surgical procedure. However, opioid-related adverse events are common, namely, respiratory depression, drowsiness, sedation, postoperative nausea and vomiting, pruritus, urinary retention, and ileus. All of these may lead to morbidity, mortality, prolonged length of stay, increased healthcare costs, and development of chronic pain.[1] Apart from perioperative complications, opioid-based analgesia is also recognized as one of the potential causes of the opioid crisis in America, which involves 2 million individuals with opioid-use disorder and a substantial economic cost estimated at nearly US$80 billion annually.[3]

The ERAS Society strongly recommends a multimodal analgesia regime in their guidelines. The principle of multimodal analgesia is to use different classes of medications to act on multiple pain receptors, aiming to achieve optimum pain control while minimising the side effects of each drug. Multiple studies have yielded

promising results where a multimodal analgesia regime is associated with early mobilisation, fast return of bowel function, fewer perioperative complications, and reduction in length of stay.[1]

The ERAS service was started in Hospital Sultanah Aminah in 2018 with the collaboration between the Department of Anaesthesia and the Department of General Surgery. A well-written ERAS protocol has been implemented and adapted to local practices since then. A local study showed that the length of hospital stay decreased from 6 days to 5 days after the implementation of the ERAS protocol. Besides that, the readmission rate decreased significantly from 17.4% to 8.6% and zero mortality was recorded throughout the study period.[4]

While most studies have concluded that multimodal analgesia is beneficial, it has significant limitations, particularly in elderly patients due to the potential risks of polypharmacy. Elderly patients often have suboptimal liver and kidney function, leading to altered drug metabolism and exacerbation of the drugs' adverse effects. Administration of multiple drugs also increases the risk of drug-drug interactions. Some novel drug delivery systems, such as controlled-release hydrogels and nanoparticles, have been suggested to allow more targeted and sustained release of medication, thus minimising the associated side effects while optimising pain control.[5]

Although ERAS strategies have been widely accepted and implemented in current practice, there is limited data regarding their application and outcomes in the Malaysian population, particularly in colorectal surgeries. Hence, this study was conducted to examine postoperative pain scores after implementing multimodal analgesia regime as per the ERAS anaesthesia protocol.

Methods

This is a retrospective study conducted in Hospital Sultanah Aminah Johor Bahru between January 2022 and December 2023. Ethical approval was obtained from the Medical Research Ethics Committee, Ministry of Health Malaysia (Ethics approval number: 24-00484-KIQ).

A list of patients who underwent colorectal surgery complying with the ERAS anaesthesia protocol from January 2022 to December 2023 was obtained from the operation theatre office. Patients 18 years of age and above were included in the study. Exclusion criteria were patients who were given long-acting opioids during the intraoperative or postoperative period, inadequate or missing patient from the case notes, and patients who were admitted to the Post-Anaesthesia Care Unit (PACU) or Intensive Care Unit (ICU) postoperatively.

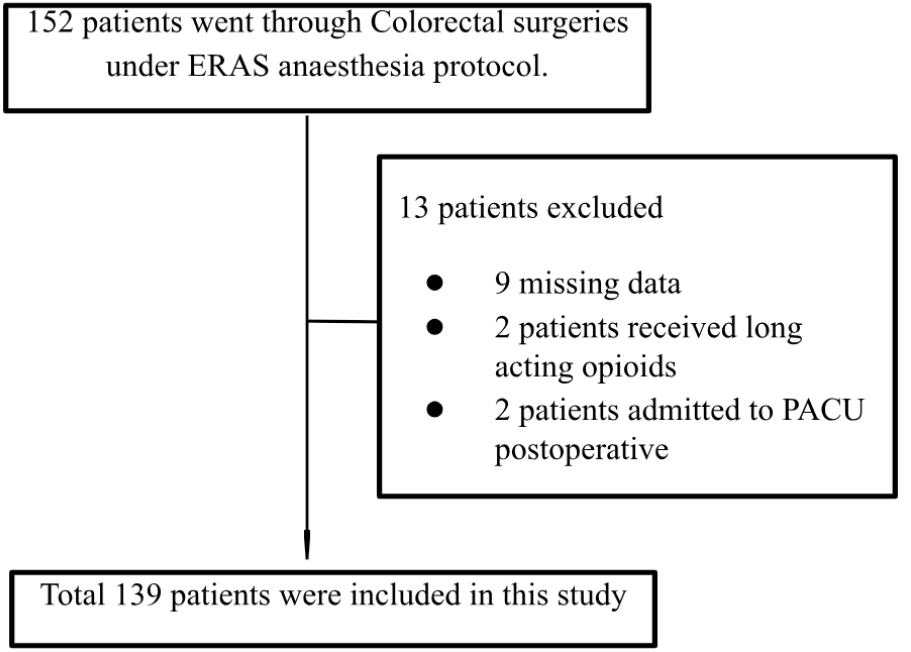

Fig. 1. Patient recruitment process.

A total of 152 patients were identified. However, 9 of them were excluded due to missing data. Compliance for documenting postoperative pain score was 94%. Two patients were excluded because they received long-acting opioids, and another 2 patients were excluded as they were admitted to PACU postoperatively. Therefore, a total of 139 cases were recruited in this retrospective study (Fig. 1).

Patient data were collected from their case notes and recorded in the data collection form (Appendix). An anonymous study identification was assigned to each patient. Personal information such as name, hospital registration number, and identity number were not recorded. Age, medical illness, American Society of Anesthesiologists (ASA) status, type of surgical procedure, and pain score on arrival at recovery bay, 6 hours postoperative, 12 hours postoperative, postoperative day 1, and postoperative day 2 were among the data collected.

All patients recruited under the ERAS program underwent induction and maintenance of anaesthesia as per protocol. Mandatory analgesics such as intravenous (IV) paracetamol, IV magnesium sulphate, IV dexamethasone, and IV parecoxib were given to all patients unless contraindicated. Analgesia infusion choice such as thoracic epidural analgesia, IV lignocaine infusion, IV ketamine infusion, and targeted controlled infusion (TCI) remifentanil would be decided by the anaesthetist of the case. Multilayer local anaesthesia infiltration upon closing of the abdomen and a continuous wound infiltration (CWI) catheter would be administered by the surgeon upon closing of the abdomen.

Postoperatively, patients were monitored in the recovery area of operation theatre for 30 minutes. Oral analgesics such as tablet paracetamol and tablet etoricoxib were prescribed before discharging patients back to the ward.

A visual analog scale was used to evaluate the patient's pain. The pain score was assessed and documented when the patient arrived at the recovery bay, postoperative 2 hours, postoperative 6 hours, postoperative 12 hours, postoperative day 1, and postoperative day 2.

IV fentanyl 50 microgram was the choice of rescue analgesia for breakthrough pain until the patient's pain score reduced to less than four. If pain control was still inadequate, patient-controlled analgesia (PCA) fentanyl would be offered to the patient.

Statistical analysis

The data were analysed using SPSS 26 (SPSS Inc., Chicago, IL, USA). We performed descriptive statistics (mean and standard deviation (SD)) on patients' demographic variables. Parametric data are presented as mean ± SD, whereas skewed data sets are shown in the median (interquartile range).

Results

A total of 139 cases were recruited in this retrospective study. Table 1 summarises the demographic data, type and duration of surgery, and ASA category of the patients. Table 2 presents the types of perioperative analgesia for all patients included in the study. Interestingly, 20 patients did not receive any analgesia infusion. However, almost half of these patients required rescue analgesia at recovery bay and 2 of them were on PCA fentanyl in the ward.

Table 1. Demographic data of patients

Demographic data	Number of patients, *n* = 139
Age	63 (55–71)
Gender	
Male	92 (66.2%)
Female	47 (33.8%)
Type of surgery	
Open surgery	115 (80.42%)
Laparoscopic surgery	24 (17.3%)
Duration of surgery	150 minutes (127–186)
American Society of Anaesthesiologists category	
I	17 (12.2%)
II	113 (79.9%)
III	11 (6.5%)
IV	2 (1.40%)

Table 2. Perioperative analgesia

Choice of adjunct analgesia	Number of patients, *n* = 139 (%)	Number of patients requiring rescue analgesia* in recovery	Number of patients requiring PCA fentanyl
Lignocaine infusion	82 (59.0)	19	3
Lignocaine + ketamine infusion	17 (12.2)	2	1
Lignocaine + remifentanil infusion	5 (3.6)	1	1
Lignocaine + ketamine + remifentanil infusion	3 (2.2)	2	0
Ketamine infusion	1 (0.7)	0	0
Remifentanil infusion	8 (5.8)	4	3
Not on analgesia infusion	20 (14.4)	8	2
Epidural	1 (0.7)	0	0

*IV fentanyl 25–100 µg

Table 3. Summary of postoperative pain score

Postoperative duration	Median pain score (interquartile range)	
	At rest	Upon movement
Upon arrival to recovery bay	0 (0–2)	1 (0–4)
2 hours	0 (0–3)	3 (0–4)
6 hours	0 (0–2)	3 (2–4)
12 hours	0 (0–1)	3 (2–3)
1 day	0 (0–2)	2 (1–4)
2 days	0 (0–1)	2 (0–3)

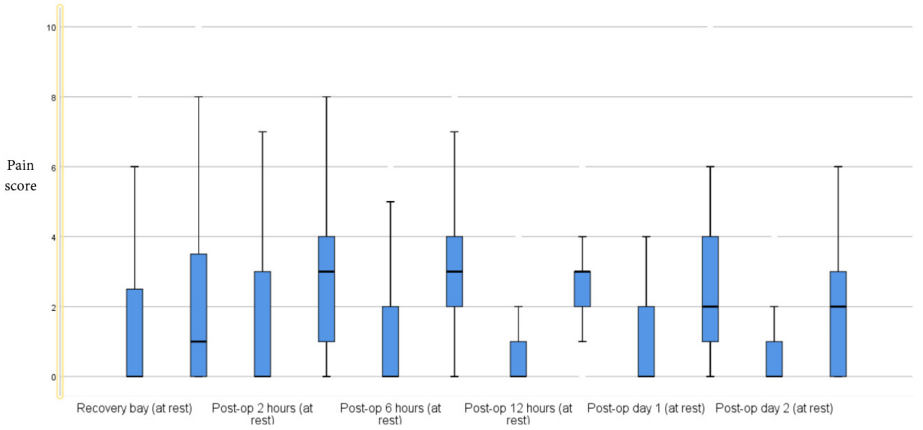

Fig. 2. Summary of postoperative pain score

Table 3 and Figure 2 show the summary of postoperative pain score from the patients' arrival at the recovery bay post operation up to postoperative day 2. The Kolmogorov-Smirnov test was performed to test on normality of the data, which reflected that all the postoperative pain score data were non-parametric data with $p < 0.05$. The median postoperative pain scores at rest were consistently 0 from arrival at recovery bay to postoperative day 2. On the other hand, the median pain score upon movement was 1 (range 0–3) when the patients reached the recovery bay, persistently 3 at postoperative 2 hours, 6 hours, and 12 hours, after which the median pain score upon movement became 2 on postoperative days 1 and 2. Throughout the postoperative period, the median pain scores at rest and upon movement were less than 4, which did not require any further pain intervention.

Discussion

The opioid crisis has significantly impacted the healthcare system in the United States leading to increased addiction rate, overdoses, and deaths.[3] Fortunately, the opioid crisis is not happening in Malaysia yet, but it is a growing concern over widespread use of opioids perioperatively. The postoperative period is a particularly vulnerable time as opioids have traditionally been used for pain management. Thus, multimodal analgesia is emerging as an alternative for managing postoperative pain effectively without relying heavily on opioids.

The ERAS Protocol consists of 20 components that involve multiple teams including surgeons, anaesthesiologists, nurses, dieticians, physiotherapists and others. However, the involvement of a multidisciplinary team requires a higher level

of communication to ensure good collaboration between different teams in terms of preoperative nutrition optimisation, intraoperative fluid management, perioperative pain management, and postoperative rehabilitation. This has not only increased the difficulty to ensure compliance in every step but also created more challenges to conduct a study or audit for systematic performance assessment. The primary outcome in studies related to ERAS has been the length of hospital stay.[4,5] To date, almost none of the studies conducted in Malaysia examine the pain score after implementing a multimodal analgesia regime as per ERAS protocol for colorectal surgeries.

The involvement of multiple teams in ERAS and low compliance with the protocol are the main reasons for the lack of data, especially in Malaysia, despite the ERAS protocol being widely accepted and practised locally. Despite the difficulties, the importance of complying with the protocol needs to be highlighted and re-emphasised as it significantly improves patients' clinical outcomes.[5]

The latest ERAS guidelines in colorectal surgeries recommend multimodal opioid-sparing analgesia to avoid the untoward effects of opioids. In our centre, IV lidocaine infusion is one of the non-opioid analgesics frequently used in surgeries compliant with the ERAS protocol. In addition to its well-known direct local anaesthetic effect, it also has antinociceptive, antihyperalgesic, and anti-inflammatory properties. Lidocaine infusion has been proven to reduce postoperative pain, particularly in the early postoperative period after laparoscopic and open abdominal surgery.[6] The recommended loading dose for IV lidocaine is 1.5 mg/kg administered over 10 minutes, then starting the infusion at 1.5 mg/kg/hour. These doses are generally safe after considering factors affecting lidocaine metabolism and clearance, such as heart failure, hepatic and renal impairment, volume of distribution, protein binding, and drug-drug interaction. Despite widespread use of IV lidocaine infusion in our centre, there has been no occurrence of local anaesthetic systemic toxicity.[7]

Ketamine is one of the options in the multimodal analgesia regime. It has a strong analgesic effect but only affects minimally on respiratory depression. Ketamine infusion has been proven to decrease postoperative opioid requirements, reduce postoperative pain scores, and increase time to first rescue analgesia. Ketamine is associated with the neuropsychiatric manifestation postoperatively, but the incidence of this side effects varies with the total dose of ketamine and the timing of ketamine administration.[8] We have frequently added a ketamine infusion if there was unsatisfactory pain control from lidocaine infusion alone and so far there have been no significant adverse events, such as delirium, that required intervention at our centre.

Remifentanil has unique pharmacokinetic profiles where it has a very short context sensitive half-time despite being given as a prolonged infusion. Thus, it is one of the preferred medications to use during induction of anaesthesia as an adjunct for monitored sedation as well as for postoperative pain management. However, remifentanil infusion is associated with opioid-induced hyperalgesia (OIH) in a dose-dependent fashion. One systematic review has reported OIH even at doses as low as 0.1 μg/kg/min.[9] Hence, remifentanil infusion is less favoured in our centre.

Thoracic epidural analgesia is recognized as the gold standard for patients undergoing open colorectal surgery as it not only offers excellent pain control but also reduces the neuroendocrine and metabolic responses to surgery.[1] Although many advantages can be observed from thoracic epidural analgesia, it is not without complications. Examples of complications that have been reported include hypotension, urinary retention, partial or patchy block and, in rare cases, devastating neurological injuries such as epidural hematoma.[10] A case of epidural abscess that led to permanent sequelae was observed with an occurrence of 1 in 3126 in a single-centre study in Italy.[11] Besides that, thoracic epidural analgesia is unable to block sacral nerves adequately; thus, it may not be suitable for all colorectal surgeries, such as abdominal-perineal surgery.

All our patients in the ERAS program were offered CWI. Multiple studies have shown that CWI is able to provide adequate pain relief, reduce opioid consumption, reduce opioid-related complications, and at the same time accelerate postoperative recovery.[12] A systematic review performed in 2013 showed that there were no significant differences in postoperative pain scores comparing epidural analgesia and CWI following abdominal surgeries.[13] Thus, the CWI technique is preferred in our centre, as it has multiple benefits that are comparable to epidural analgesia but avoids hazardous complications associated with thoracic epidural analgesia.

This study has several limitations. Firstly, the analgesia infusions were not standardised in all patients. The choice of analgesia infusion depended on the anaesthesiologist in charge of the case and patients received different types of analgesia regimes intraoperatively, which has limited the generalisability of our findings. Secondly, the types of surgery were not equally distributed in our study, in which 82.7% of patients underwent laparotomy while the rest underwent laparoscopic surgery. Pain intensity in laparotomy surgery is more severe than in laparoscopic surgery. Nevertheless, our study shows a promising result in postoperative pain score with the multimodal analgesia regime.

The ERAS protocol has not only demonstrated good clinical outcomes but also reduced the average length of hospital stay, promoted hospital bed turnover rate, and reduced the healthcare cost.[14] Multimodal analgesia certainly is one of the core components that makes ERAS a successful program. This study shows a good outcome following a multimodal analgesia regime in colorectal surgery. However, the level of evidence is limited by its retrospective design. More prospective studies with standardised interventions and control groups shall be done in future to examine the outcome of multimodal analgesia protocols and provide stronger evidence of efficacy.

Conclusion

Based on the findings of this retrospective study, we conclude that multimodal analgesia in line with the ERAS protocol in colorectal surgeries is feasible, safe, and efficient as it yielded a promising result, which leads to effective pain control and quicker recovery, and aligns with global trends to minimise opioid use postoperatively.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Medical Research Ethics Committee, Ministry of Health Malaysia (Ethics approval number: 24-00484-KIQ). In view of the retrospective nature of this study that collected data from patient case notes without interaction with actual patients, informed consent was waived.

Competing interests

None to declare.

Funding

None to declare.

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Appendix

A. Data collection form

Version 2.0, dated 20/3/2024

DATA COLLECTION FORM
MULTIMODAL ANALGESIA AS PART OF ENHANCED RECOVERY AFTER SURGERY (ERAS) IN COLORECTAL SURGERY

Assigned ID :
Diagnosis :
Age :
Performed Surgery :
Surgery Date :

Patient's demographic

ASA : I / II / III / IV

Comorbids : Hypertension / DM / CKD / ESRF / IHD / Smoker / Obesity / Others:

_____

BMI : _____ kg/cm^2 **Weight** : _____ kg **Height** : _____ cm

Pre-operative (Sedative premedication should be avoided)
If given: _____ Reason:
_____

Intra-operative
Anesthetic maintenance : Desflurane + N2O / Desflurane + Air / TIVA / If others, state reason:

Analgesia

IV Paracetamol	1g / _____mg
IV Dexamethasone	4mg/8mg
IVI Lignocaine	_____ mg / kg / H
IVI $MgSO_4$	
IVI Ketamine	
IVI Dexmedetomidine	
TCI Remifentanil	
Epidural infusion	
Others	
Multilayer LA infiltration by surgeon : Yes / No	

Post-operative

Analgesia		**Pain score**	**Recovery room**	**Ward**				
			Arrival time:	**2H**	**6H**	**12H**	**POD1**	**POD2**
PCA								
CWI		At rest						
Epidural		At movement						
Regional block		✱Rescue analgesia						
Others		**Level of activity** (1: sit up on bed ; 2: sit out of bed ; 3: sit out of bed >3H ; 4: ambulating with assistants)						
Oral analgesia		T. Paracetamol						
		T. Etoricoxib / T. Celecoxib						
		Others						

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Going beyond iron studies for iron deficiency anaemia: new cellular biomarkers for diagnosis

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Abstract

The full blood count is one of the simplest and most ordered blood investigations in daily practice. Its use and that of other classic markers for iron deficiency have been well established. Recently, there has been increased attention to the potential for fluorescence flow cytometry as an enhancement to the classic blood count. This paper explores the potential of new cellular biomarkers using this technology to enhance our diagnosis of iron deficiency anaemia (IDA) and differentiate between sepsis and systemic inflammation. For IDA, parameters such as the reticulocyte haemoglobin equivalent (RET-He) and the difference between reticulocyte and erythrocyte haemoglobin equivalent (DELTA-He) are exciting additions to enhance the speed and accuracy of its diagnosis. RET-He, which is defined as the haemoglobin content in reticulocytes, offers a more immediate reflection of iron availability for erythropoiesis compared to traditional markers such Hb concentration and mean corpuscular volume. The integration of advanced technologies, such as fluorescence flow cytometry, into routine blood counts can significantly improve diagnostic precision, allowing for a more nuanced understanding of the haematopoietic system and immune response. In critically ill patients,

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these new parameters can help to differentiate between various inflammatory responses and infections, providing valuable insights into the activation status of neutrophils and other immune cells. Parameters such as immature granulocytes and neutrophil reactivity intensity have shown promise in discriminating between systemic inflammatory response syndrome and sepsis. The introduction of these markers holds the potential for quicker and more cost-effective assessments for sepsis. The addition of fluorescence flow cytometry parameters to our armament of investigations for blood counts could enhance our abilities to practice precision medicine.

Keywords: cytometry, anaemia, sepsis, reticulocyte, immune response

Introduction

The continuous flow of blood through the body ensures that the tissues and organs receive the vital supplies required to survive, and waste products are removed. The various cells within the blood stream function as carriers, as defenders and perform repairs when required. As such, analysis of the blood cells would show great insight in the overall health of the body.

The full blood count is one of the simplest and most ordered blood investigations in daily practice. It allows the clinician to review the key components of blood, namely the oxygen carrying capacity through measurement of haemoglobin (Hb), the leucocyte counts, and the platelet counts. This provides a quantitative overview of the haematopoietic system and allows the clinician to infer various conclusions with regards to oxygen carrying capacity and the body's immune response. In this review, we explore the potential of the new parameters using fluorescence flow cytometry enhancing diagnostic performance in iron deficiency anaemia (IDA) and sepsis.

New parameters from the blood count reflect the immune response

The COVID pandemic highlighted the devastation that a systemic inflammatory disease can have on our patients as well as on the healthcare system. The various biomarkers used to measure the inflammatory response were wrought with a lack of specificity and sensitivity to predict disease progression accurately.[1] There is no single biomarker that can accurately differentiate between a bacterial, viral

or systemic non-infectious reaction (SIRS). The introduction of fluorescence flow cytometry in modern blood count analysers may offer a useful tool in our armament to detect and differentiate between infection and inflammation.[2]

Advanced inflammatory parameters from the routine blood count can provide important initial information within minutes at the start of the diagnostic process. They provide quantitative and qualitative information about the status of the patient's immune system, which can allow conclusions to be drawn about the type and severity of the infection. The fluorescence flow cytometry of modern blood count analysers makes it possible to analyse the leukocyte populations in greater depth and provides an insight into the status of the immune response. The activity of neutrophil granulocytes and lymphocytes plays a major role in bacterial and viral infections, and reacts at a very early stage of the immune response.

Both systemic-inflammatory (non-infectious) and infectious inflammations result in an immune system response in which different cells show more or less activation depending on the trigger. The innate immune system is a first non-specific line of defence against pathogens. It is divided into 2 areas: an early, cell-based immune response, characterised by an increase in activated T lymphocytes and NK cells, and a humoral immune response, characterised by activated B lymphocytes (plasma cells). Its main function is to identify and remove foreign substances by specialised leukocytes in order to activate the adaptive (acquired) immune system through presenting the antigen of the pathogen for recognition. In the first phase of the innate immune system, the number and activity of activated neutrophils increase (NEUT-RI, NEUT-GI*),* activated monocytes (RE-Mono), and immature granulocytes (IG) are typically observed. In addition, more reactive lymphocytes (RE-LYMP) and T-cell-independent activated plasma cells (AS-LYMP) can be observed. The combination of the RE-LYMP and AS-LYMP parameters provides additional information on the cellular activation of the innate and adaptive immune system.

Measurement technology

Fluorescence flow cytometry enables the identification and quantification of cell populations based on their fluorescence parameters and light-scattering properties.

Detergents are used to increase permeability of cell membranes and to enhance specific fluorescence marker to bind to intracellular ribonucleic acids (RNA). Given that activated but also immature cells (lymphoid, granulocytic, and monocytic)

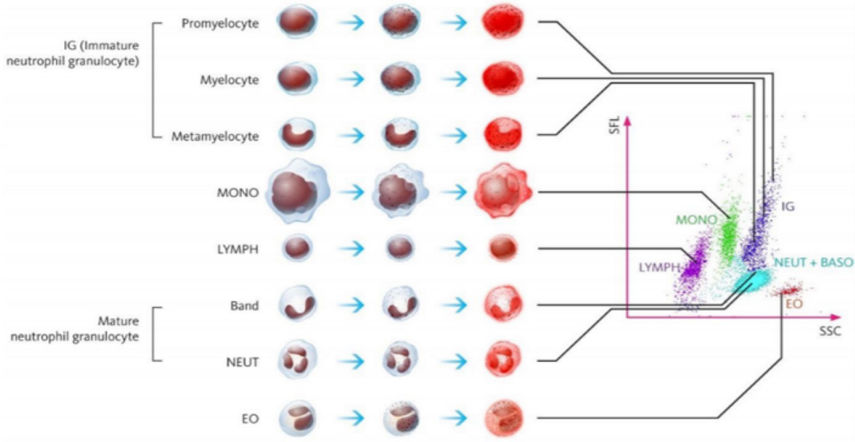

Fig. 1. WDF scattergram: differentiation of leukocytes. Adapted from Sysmex Systems, Kobe, Japan.[3]

have an altered lipid membrane composition, the cell permeability for the lysis reagent used on the haematology system is higher compared to non-activated or mature cells, and cellular nucleic acids can be stained more intensively with a fluorescent marker. Each cell is detected by a laser beam in a sheath current method.

The 3 signal intensities measured are:

- Forward scattered light (FSC): indicates the size of the cells.
- Side scattered light (SSC): indicates nuclear shape and surface structure.
- Side fluorescence light (SFL): indicates the labelling of nucleic acids and determination of activity intensity.

These measurements are used in all Sysmex XN systems (Sysmex Systems, Kobe, Japan) for counting and differentiating leucocyte populations, nucleated erythrocyte precursors, reticulocytes, and the flow cytometric measurement of thrombocytes. The measurements are reported as a white blood cell differential fluorescence (WDF) scattergram (Fig. 1).

Clinical benefits of the extended blood count parameters

According to the current state of research, the clinical benefit of these extended blood count parameters lies in the major fields of anaemia diagnostics and infection diagnostics. These 2 areas are closely linked from a diagnostic point of view. During inflammation, the acute phase reaction results in fever, leucocytosis, and production of acute phase proteins (APP) such as hepcidin. Hepcidin, a key regulator of iron homeostasis in the body, is an APP expressed in the liver that decreases iron availability to inhibit bacterial DNA synthesis, and enzymatic function. Its expression leads to iron-restricted erythropoiesis. At the same time, commonly used parameters to diagnose anaemia are compromised. Ferritin, being an APP itself, is falsely increased, whereas transferrin decreases.[4]

Table 1. Overview of the extended blood count parameters of the XN series with their respective immunological interpretation, units, and reference intervals.

Cell population and/or properties	Immunological interpretation	Parameter	Unit	Reference interval
Total number of reactive lymphocytes	Increased in innate and cell-based adaptive immune response	RE-LYMP# RE-LYMP%[I]	Cells/L %	0–0.5 x 109/L 0–5 %
Antibody-forming lymphocytes[II]	Increased in innate and humoral adaptive immune response	AS-LYMP# AS-LYMP%[I]	Cells/L %	0 cells/L 0%
Granularity of neutrophils	Increased in early innate immune response	NEUT-GI	SI	142.8–159.3 SI
Reactivity of the neutrophils	Increased in early innate immune response	NEUT-RI	FI	39.8–51.0 FI
Immature granulocytes	Indicates the severity of an infection	IG# IG%	Cells/L %	0–0.06 x 109/L 0–0.6 %
Delta haemoglobin equivalent	Detects a systemic bacterial infection at a very early stage	DELTA-He	pg	1.7–4.4 pg
Reticulocyte haemoglobin equivalent	Current availability of iron for the reticulocytes	RET-He	pg	29.7–35.4 pg

#: count; %: percentage; SI: scatter intensity; FI: fluorescence intensity; pg: picogram
[I]As a percentage of all white blood cells.
[II]If antibody-forming lymphocytes (AS-LYMP) are present, these are also recorded in the number of all reactive lymphocytes (RE-LYMP).
Adapted from Pekelharing *et al.* 2010.[2]

This is where the parameters of reticulocyte haemoglobin equivalent (RET-He) and the delta haemoglobin equivalent (DELTA-He) help, as they are not masked by the acute phase reactions. Table 1 summarises the extended blood count parameters from fluorescence spectrometry.

Anaemia diagnostics with extended parameters from the blood count

Anaemia is one of the most common diagnoses in anaesthesiology and intensive care medicine. Anaemia describes the lack of erythrocytes or Hb and can, under certain circumstances, lead to an undersupply of oxygen to vital organs. According to the World Health Organization (WHO), anaemia is defined by values of Hb < 12 g/dl in women and Hb < 13 g/dl in men.[5]

Approximately 30% of all surgical patients are already anaemic before an operation. A low Hb value is often regarded as an indication for a transfusion with red blood cell (RBC) concentrates instead of considering clinical options to improve oxygen supply. RBC transfusions are associated with a multitude of risks and side effects. These include allergic reactions as well as haemolytic and non-haemolytic transfusion reactions. In addition, it should not be forgotten that a blood transfusion can also be described as a "transplantation of the liquid organ blood", during which millions of foreign cells are introduced into the recipient's body. Such an intervention not only interferes with the patient's immune system but can also put additional strain on the patient's recovery. The immune modulation that this may trigger could be associated with an increased nosocomial infection rate and is currently the subject of clinical investigations.[6]

Since 2011, the WHO has been calling for the introduction of a medical concept to increase patient safety by strengthening the body's own blood reserves in everyday medical practice, aptly named patient blood management.[7] The concept is based on 3 pillars: early diagnosis and treatment of any anaemia that may be present, minimisation of blood loss, and rational use of blood reserves. Preoperative anaemia is associated with a longer length of hospital stay, higher risk of infection, higher risk of kidney damage, and mortality. These patients also often require more blood transfusions. According to one study, 11–48% of surgical patients suffer from anaemia at the time of surgery and are therefore at high risk of blood transfusion, which is not much lower even in patients with latent anaemia.[8] Even patients who stay in intensive care for a longer period after surgery and initially have a normal Hb value often develop iron deficiency or anaemia during their stay due to, *e.g.*, daily blood sampling.

Determination of Hb is the standard for the diagnosis of anaemia.[9] However, Hb only reveals an iron deficiency if the iron stores have already been depleted and/or iron has been insufficiently available for haematopoiesis for a long time, as can be the case in patients with chronic inflammation, for example. This parameter is not able to recognise acute or latent iron deficiency at an early stage, as it depends on the lifespan of erythrocytes.

RET-He and DELTA-He

RET-He indicates the Hb content of the reticulocytes. It is a useful parameter for the diagnosis and therapy control of iron deficiency anaemia.[10] The lifespan of circulating erythrocytes is approximately 120 days. Therefore, iron deficiency states and changes in the iron supply to erythropoiesis are detected relatively late using Hb concentration, mean corpuscular erythrocyte volume, mean corpuscular haemoglobin content, or the proportion of hypochromic erythrocytes. Reticulocytes, the precursor cells of mature erythrocytes, are formed in the bone marrow and washed out into the bloodstream. In the peripheral blood, the reticulocyte usually develops into a mature erythrocyte within 2 days. Determination of the reticulocyte count therefore provides very prompt quantitative information about erythropoiesis in the bone marrow. Determining the Hb content of the reticulocytes provides information about the current iron supply and thus enables a qualitative assessment of the cells so that changes in the iron status can be identified earlier than by determining the Hb content of the mature erythrocytes.

The reference range for RET-He is 28–35 pg. Iron deficiency is present at less than 28 pg. In a consensus document on the treatment of postoperative anaemia by Munoz *et al.*, RET-He is described as a marker equivalent to transferrin saturation and ferritin for the detection of iron deficiency, but unaffected by the acute phase reaction.[8] A reticulocyte (RET) scattergram is shown in Figure 2.

DELTA-He is the calculated difference between haemoglobinisation of reticulocytes (RET-He) and the Hb concentration of mature erythrocytes. In normal physiological conditions, DELTA-He is a positive value between 1.7 and 4.4 pg, as reticulocytes show a slightly higher Hb equivalent than mature cells.[11] In an acute phase reaction, the RET-He decreases very quickly because the increased release of hepcidin by interleukin-6 (IL-6) immediately leads to iron deficiency in the bone marrow. DELTA-He reflects this shift in haemoglobinisation between mature and immature erythrocytes within a few hours.

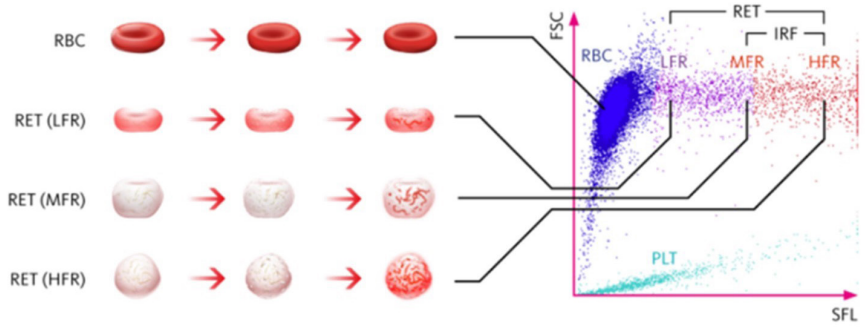

Fig. 2. RET scattergram: differentiation of erythrocytes. Adapted from Sysmex Systems, Kobe, Japan.[3]

In their review, Hönemann *et al.*, recommend RET-He as a routine preoperative parameter to identify patients with latent iron deficiency at low cost.[12] In terms of perioperative prehabilitation and the concept of "enhanced recovery after surgery" (ERAS), patients with iron deficiency could be treated proactively at an early stage to prevent complications, and avoid prolonged hospitalisation.

The determination of RET-He and DELTA-He in the blood count is already available in many hospitals and can replace the classic parameters of ferritin, transferrin, and iron as they are more sensitive, specific, and faster.

Infection diagnostics with extended parameters from the blood count: support in sepsis diagnostics

Sepsis is defined as a systemic, dysregulated reaction of an organism to an infection leading to a life-threatening condition.[13] Positive pathogen detection, *e.g.*, with a positive blood culture, increases the likelihood of an infectious cause of acute illness as well as the diagnosis of sepsis. However, laboratory diagnosis of infection takes 2 days at the earliest, potentially leading to a delay in diagnosis. Conventional parameters such as procalcitonin are not recommended to guide antimicrobial initiation. Cellular markers, such as leucocytes and thrombocytes, are far too unspecific for recognising sepsis.

Neutrophil reactivity intensity

Neutrophil granulocytes play a major role in inflammation. Activated neutrophils secrete a variety of proinflammatory cytokines to attract further immune cells and lysozyme to kill the pathogens. The neutrophil reactivity intensity (NEUT-RI) parameter shows the reactivity intensity of the neutrophils and represents their metabolic activity. Elevated NEUT-RI values reflect the activation of RNA biosynthesis in the neutrophils. This activation of neutrophils is the first event of the immune response to bacterial infections after the onset of infection.[14] Healthy patients show a reference interval of 39.8–51.0 fluorescence units (FI).[14] A NEUT-RI greater than 51.6 FI indicates a bacterial infection. [11] The differentiation between healthy and septic patients is reported with an area under the curve (AUC) of 0.909, sensitivity of 71.3%, and specificity of 96.8%. In a publication by Urrechaga *et al.*, NEUT-RI values over 54 FI can distinguish patients with non-systemic infections from septic patients (AUC 0.825, sensitivity 83.5%, specificity 68%).[15] Stiel *et al.* showed that the NEUT-RI parameter had a high sensitivity and specificity in the diagnosis of disseminated intravascular coagulopathy in patients with septic shock.[16]

Immature granulocytes

The presence of immature granulocytes (IG) is indicative of an increased consumption of neutrophil granulocytes in the periphery and points to a bacterial infection. This does not apply to patients undergoing chemotherapy or glucocorticoid therapy, nor to patients with underlying haematological disease or pregnant women. In healthy individuals, IG are almost never found in the blood. Ayres *et al.* describe that IG > 0.3% for the discrimination of SIRS and sepsis according to blood culture has an AUC of 0.75, sensitivity of 75.7%, and specificity of 45.5%. An IG value greater than 2% already shows a specificity of 90% with a sensitivity of 69.8%.[17] Nierhaus *et al.* state that IG was superior to C-reactive protein (CRP), lipopolysaccharide binding protein, and IL-6 in the discrimination of SIRS against sepsis in the first 48 hours in the intensive care unit.[18] In order to provide rapid and meaningful support in sepsis diagnostics with parameters from the blood count, it is possible to obtain an indication of the exclusion of sepsis or the very high probability of the presence of sepsis with various parameter combinations. With the help of the NEUT-RI, IG, and DELTA-He parameters, these indications can be generated for the treating physicians via so-called rule sets in a work area management system (Fig. 3).

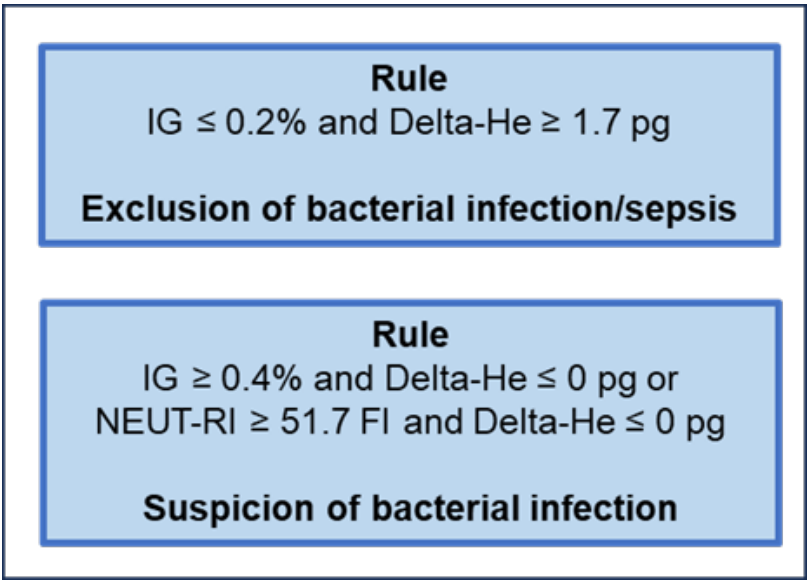

Fig. 3. General guide to using the new parameters to exclude or suspect a bacterial infection.

Differentiation of bacterial or viral infections using RE-LYMP/AS-LYMP

The RE-LYMP parameter is used to record activated T lymphocytes and B lymphocytes. AS-LYMP is the quantification of highly fluorescent lymphocytes, such as antibody-producing B lymphocytes and plasma cells. In contrast to IG, RE-LYMP, and AS-LYMP are mainly elevated in viral infections.

Support in assessing the course of disease in COVID-19 patients

In a multicentre study of 12 European hospitals with 1000 hospitalised COVID-19-positive patients, Linssen *et al.* described the development of a prognostic score to identify critically ill patients with a SARS-CoV-2 infection at an early stage and evaluate the need for critical care.[19] The score included 10 parameters from the blood count of the Sysmex XN series predicting requirement of critical care within the next 14 days, as well as recovery after 3 days of admission. With an AUC of 0.875, the score performed better than any other individual parameter including

the neutrophil/lymphocyte ratio at a value of > 3 at recognising a critical situation in patients. It correctly discriminated 70.5% of COVID-19 patients into critical and non-critical disease progression just 3 days after hospitalisation, and on day 6 of hospitalisation, 93% of patients were correctly identified as critically ill and requiring intensive care. The COVID-19 Prognostic Score enables early detection of critical disease progression, assessment of the need for intensive medical care, and allocation of resources.

Intensive Care Infection Score

Weimann *et al.* published the Intensive Care Infection Score (ICIS), a diagnostic score for the early detection of bacterial infections in postoperative intensive care patients.[20] The score combines 5 parameters from the blood count, some of which are immediately elevated (NEUT-RI) while others increase with the progression of infection (NEUT, IG, DELTA-He, AS-LYMP). With an AUC of 0.852, a sensitivity of 82.93%, and a specificity of 75.11%, the ICIS outperformed conventional sepsis markers such as CRP (AUC 0.77, sensitivity 82.93%, specificity 54.4%) or PCT (AUC 0.696, sensitivity 73.17%, specificity 58.56%). ICIS can be determined within few minutes and facilitates diagnosis and monitoring of infection. ICIS is currently available at research level and can be used for study purposes on request if the system requirements are met.

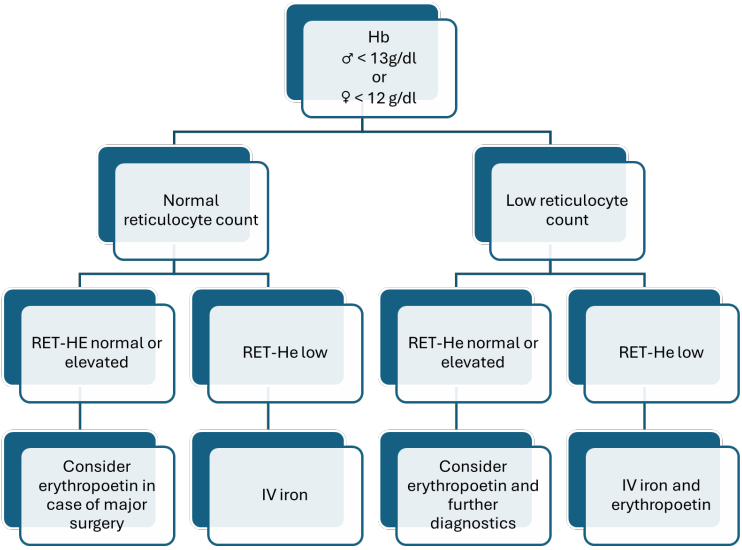

Fig. 4. Algorithm to assess and treat preoperative anaemia (own representation).

Routine parameters in preoperative anaemia management

Especially at the time of elective surgery, it is extremely important that patients are optimally prepared considering potential blood loss and decrease of Hb during and after surgery. Patients with a diagnosed iron deficiency and additional inflammation are at high risk to prolonged stay in hospital. According to Froessler *et al.*, the length of hospital stay could be reduced by 3 days in patients with preoperative anaemia if they were treated with intravenous iron.[21] Anaemia should be treated preoperatively using Hb, RET-He, and reticulocyte count, as shown in (Fig. 4).

Summary

The interpretation of the new extended blood count parameters described in this review makes it possible to obtain additional information for diagnosis and treatment decisions cost-effectively and, above all, quickly. These diagnostic parameters help to diagnose and treat patients with inflammatory diseases, to differentiate between viral or bacterial sources of infection, to initiate antimicrobic medication, and to monitor therapy as they provide additional information regarding immune response activation and quantitative assessment of the activation status of neutrophils (NEUT-RI, NEUT-GI), IG, and activated lymphocytes (RE-LYMP, AS-LYMP). Further clinical prospective investigations are essential to improve clinical interpretation.

In addition, the RET-He and DELTA-He parameters help to assess available iron and to diagnose iron deficiency in the acute phase. RET-He is an early indicator of response to iron therapy and/or erythropoiesis-stimulating agents allowing for evaluation of therapy success within 2 to 4 days. Furthermore, DELTA-He appears to be an early indicator of infections and helps to discriminate between IDA and anaemia in inflammation.

Many laboratories in Malaysia have the capabilities to run these tests, but they are currently not requested as part of the standard blood count. The possibility of enhancing our diagnosing capabilities for anaemia and sepsis makes these new markers an exciting possibility for advancing perioperative and intensive care.

Declarations

Ethics approval and consent to participate

This review article did not require ethics approval or informed consent.

Competing interests

Christian Honemann, MD, PhD, received honoraria for talks and travel expenses from Draeger Medical (Germany), CSL Vifor Pharma (Germany), and Sysmex Europe (Netherlands). Marie-Luise Ruebsam, MD, has received one author honorarium from Sysmex Europe and one from Draeger Medical. Kevin Ng Wei Shan reports no competing interests.

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None to declare.

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"Cannot intubate, cannot oxygenate" and eFONA: a narrative review

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Abstract

The "cannot intubate, cannot oxygenate" (CICO) event is a very rare airway crisis. The ensuing airway management is time-sensitive and if not managed promptly, CICO can lead to hypoxic brain injury or death. The identification of the cricothyroid membrane may be challenging when under stress, especially in certain patients, such as those with obesity and short neck. Thus, airway ultrasonography can be a useful aid in identifying the membrane. The emergency front of neck access (eFONA) rescue is performed using various methods, including needle cannula cricothyrotomy, scalpel-bougie method, traditional open cricothyrotomy, or using a commercial kit. The 4th National Audit Project reported a 60% failure rate of needle cricothyrotomy when it was the first eFONA choice, compared to 100% success rate when surgical cricothyrotomy was selected as the first airway rescue method. Thus, the Difficult Airway Society's recent guidelines recommend the scalpel-bougie technique. Apart from retaining the eFONA skills by training, education, and

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cognitive aids, patient safety can also be improved at the institutional administrative level by establishing airway equipment standardisation and a multidisciplinary airway management team.

Keywords: CICO, cricothyrotomy, difficult airway, eFONA

Introduction

"Cannot intubate, cannot oxygenate" (CICO) describes a life-threatening airway emergency encountered in anaesthesia and emergency medicine. This situation arises when attempts to secure the airway through conventional intubation techniques have failed and non-invasive methods to provide adequate oxygenation, such as mask ventilation or supraglottic airway devices, are also unsuccessful.[1] If not managed promptly, the CICO scenario, which represents one of the most feared complications in airway management due to its potential for catastrophic outcomes, can result in hypoxic brain injury or death.[1,2]

Incidence and outcomes

According to data from the 4th National Audit Project (NAP4), severe complications from CICO, including death, occur in roughly 1 in 180,000 anaesthetic cases, with poor preoperative airway assessment being a significant contributing factor.[1] In a developed Asian country such as Japan, the incidence of CICO has been well-documented. A multicentre study in Japan reported a CICO incidence of 3 cases out of 97,854, all occurring under general anaesthesia, corresponding to an incidence rate of 0.003%.[3] In each of these 3 instances, emergency tracheotomy was ultimately required to secure the airway. Two of the patients experienced full recovery without any neurological deficits; however, the third case resulted in severe and irreversible brain damage due to prolonged hypoxia. Data from the first National Audit on Anaesthetic Airway Management, conducted across 14 Malaysian Ministry of Health hospitals, provided a broader regional context. The audit found that the incidence of CICO necessitating an emergency surgical airway was 20 cases per 100,000 anaesthetic procedures, higher than in other developed countries.[4] Although the absolute risk of CICO is low, this data is alarming and should not be underestimated.

The outcomes of CICO can range from complete recovery to severe neurological impairment depending on the timeliness and effectiveness of the emergency

airway management. These severe critical incidents have prompted recommendations for rigorous preoperative assessment and adherence to protocols such as those of the Difficult Airway Society (DAS), which aim to mitigate such risks by outlining clear guidelines for emergency management.[5] Recent reviews highlight that, despite advances in technology and training, unanticipated difficult airways remain a challenge, emphasising the importance of immediate and decisive action in CICO scenarios.[6] As such, in a CICO scenario, emergency front of neck access (eFONA), also known as front of neck airway, is a definitive lifesaving intervention. When performed successfully, eFONA enables ventilation by accessing the anterior neck, thereby re-establishing alveolar oxygenation.[5]

Cricothyroid membrane identification

Fundamental to the successful outcome of any cricothyrotomy (cricothyroidotomy) technique is the accurate identification of the cricothyroid membrane (CTM). A clear knowledge of the percutaneous anatomical landmarks of the front of the neck is therefore essential. The conventional palpation method has been shown to be

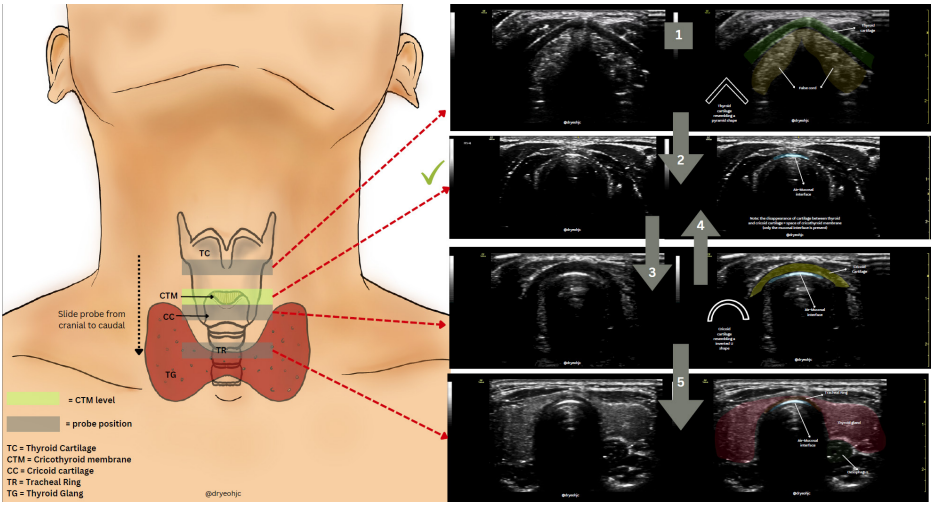

Fig. 1. The transverse approach of airway ultrasound. *(1)* Identify the thyroid cartilage (resembles a pyramid shape). *(2)* Slide down caudally until the thyroid cartilage disappears from sight, leaving the air mucosal interface alone. *(3)* Slide further down to view the cricoid cartilage (resembles an inverted U shape). *(4)* Slide cranially to visualise the space between the thyroid and cricoid cartilage, *i.e.*, cricothyroid membrane space. *(5)* Slide caudally to visualise the tracheal rings. The thyroid gland will appear as the probe moves more caudally to the sternal notch.

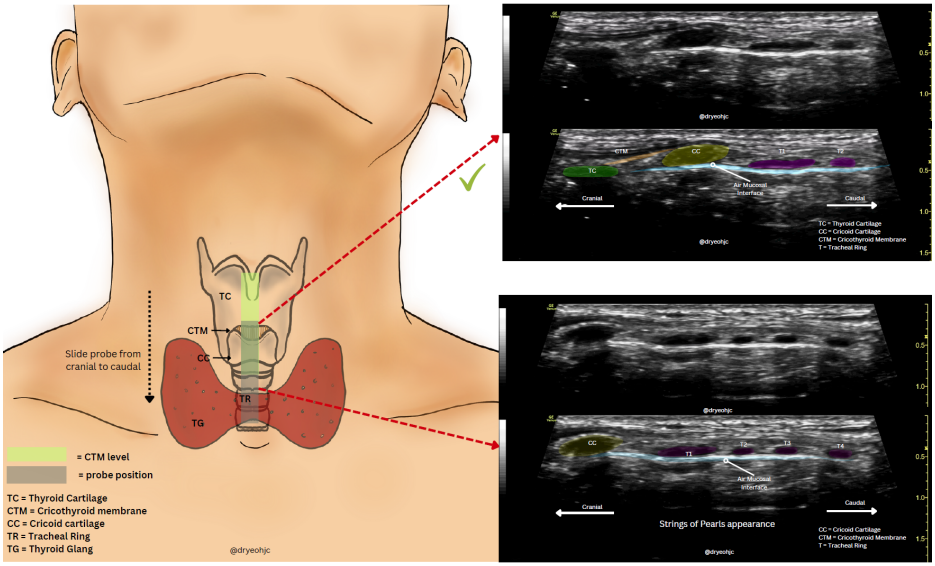

Fig. 2. The longitudinal approach of airway ultrasound. The thyroid cartilage, cricothyroid membrane, cricoid cartilage, tracheal rings, and air mucosal interface is visualised in a single view. Tip: Slide the probe left and right to obtain a true midline view, where the air mucosal interface appears as a straight hyperechoic line with its surrounding structures.

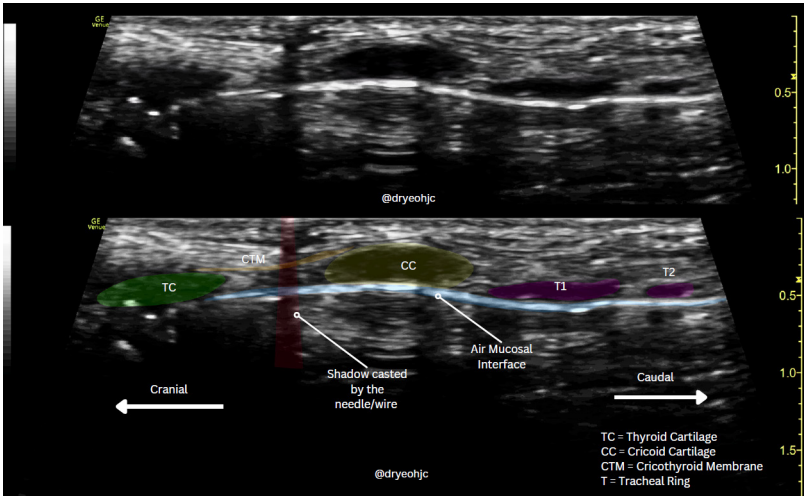

Fig. 3. A longitudinal approach of ultrasound probe shows a needle/wire casting a shadow and used to mark the location of the cricothyroid membrane.

inaccurate at determining not only the CTM, but also the midline in both obese and non-obese patients.[7-9] The more recent laryngeal handshake method, advocated by the 2015 DAS Guidelines, has been shown to be easy to learn as well as better at identifying the CTM.[5,10] However, this can also be challenging, particularly in patients with obesity, short necks, or difficult anatomy.

Ultrasound guidance is a valuable tool as it allows for real-time visualisation of the neck's anatomy and accurate identification of the CTM, which can improve the success rate and safety of this critical airway management.[11,12] The CTM can be identified using either a transverse or longitudinal approach with a high-frequency linear array transducer. The transverse view (Fig. 1) is beneficial for patients with short necks, while the longitudinal view (Fig. 2) enables the operator to visualise the thyroid cartilage, CTM, cricoid cartilage, and tracheal rings (also known as strings of pearls appearance) in a single view.[11] In addition to airway identification, both approaches allow for the identification of any major vessels or masses anterior to the CTM, further improving the safety during eFONA performance.[13]

In anticipated difficult airway cases, the surface landmarks of the neck, especially the CTM, can be marked with a marker under ultrasound guidance prior to managing the airway in case eFONA is necessary as a rescue method. Alternatively, a needle or wire can be used to identify the appropriate level of front of neck access by detecting the posterior acoustic shadowing (Fig. 3) in a longitudinal view of the airway.[12] Not only will this reduce the cognitive load on anaesthesiologists when an emergency situation arises, but a pre-procedural identification of the CTM will reduce the time to perform a cricothyrotomy whilst having a less rate of failure. Furthermore, ultrasound airway imaging can help avoid excessive deep penetration resulting in trauma to the posterior tracheal wall or creation of a false passage.[11]

Cricothyrotomy

The eFONA can be generally divided as needle cricothyrotomy (or cannula cricothyrotomy), scalpel (open) cricothyrotomy, or surgical tracheostomy. The needle cricothyrotomy involves passing an over-the-needle catheter through the CTM after bubbles are seen in a saline-filled syringe due to the needle entering the airway.[14] If successful, this provides an airway for oxygenating the patient, whereby ventilation is via a self-inflating bag-valve mask device or a low-pressure jet ventilation system (transtracheal jet ventilation).[15] Conversion to a wider, sturdier, and definitive airway, more efficient at oxygen delivery and carbon dioxide elimination is required after this initial rescue method.

While transtracheal jet ventilation (TTJV) is effective for short-term oxygenation in cases of upper airway obstruction, it is also not a long-term solution.[15] Duggan *et al.* identified significant complications with TTJV, such as barotrauma, pneumothorax, and inadequate ventilation, limiting its use in prolonged airway management.[16] Despite these drawbacks, TTJV remains a viable option primarily as a bridge to more definitive airway management strategies.[17]

The scalpel-bougie technique, endorsed by DAS in its 2015 guidelines, has become increasingly popular due to its simplicity and effectiveness in both pre-hospital and in-hospital settings.[5] This technique involves 5 simple essential steps: stabilising the larynx, identifying the CTM, making an initial horizontal incision which is widened by turning the scalpel 180°, bougie insertion into the trachea, and advancing a #6.0 endotracheal tube over the bougie. Finally, the correct tube placement is confirmed using capnography or capnometry. Its popularity arises from the minimal equipment required, making it ideal for emergency scenarios where advanced tools may not be available.

Compared to the scalpel-bougie technique, the traditional open cricothyrotomy is more equipment-intensive and is often reserved for cases involving complex anatomical challenges, such as facial trauma, extensive soft tissue injuries, or haematoma.[18] This method requires making vertical and horizontal incisions over the CTM using a tracheal hook for traction, dilating the incision, and placing a tracheostomy tube. Compared to the above techniques, the traditional open cricothyrotomy is more invasive, time-consuming, and carries a higher risk of trauma to the surrounding tissues, including haemorrhage.

The Seldinger technique, featured in several of the pre-packed commercial kits, such as the Cook Melker kit, involves inserting a needle into the CTM, verifying tracheal entry, placing a guidewire, and dilating the tract to insert the tube. It is particularly favoured in intensive care due to its lower complication rates, especially for its reduced risk of bleeding and tracheal injury.[19] Despite being less invasive than the traditional open cricothyrotomy method, the Seldinger technique is more suited to a controlled environment than the time-sensitive CICO situation.[18] Compared to the scalpel-bougie technique, Nakstad *et al.* reported the Seldinger technique poses higher risks of tube misplacement, making it less ideal in rapid high-stakes settings.[20]

The commercial kits provide the convenience of having all required components available during a critical emergency situation, rather than having to gather each separate component. However, one should be familiar with the kits, which may very well differ from one to another in terms not only of content but also as to usage instructions. Heymans *et al.* conducted a study involving 20 medical

students without prior surgical airway training who were randomly selected and trained to perform cricothyrotomy using the surgical cricothyrotomy methods and 2 different commercial kits.[21] The study concluded that surgical airway-naïve medical personnel established emergency cricothyrotomy more efficiently and safely with the surgical technique than with the commercial kits. Each institution can also assemble their own pre-packed rescue kits that can be easily accessed during a CICO event.[22]

The NAP4 reported an unexpectedly high (60%) failure rate of needle cricothyrotomy when performed as the initial CICO rescue method.[23] In contrast, there was a 100% success when surgical cricothyrotomy was the first choice of rescue method, which led to the recommendation of the scalpel-bougie technique by DAS as the rescue technique of choice. The failure of needle cricothyrotomy during the audit period was reported to have stemmed from various factors, which included the cannula directed cephalad, mechanical failure, and failure to oxygenate, among others. A recent systematic review and meta-analysis found scalpel cricothyrotomies to be quicker, have fewer complications, and superior first pass success rate compared to cannula cricothyrotomies.[24] Another advantage of the surgical airway over the needle cricothyrotomy is the provision of a definitive airway by the presence of a cuffed tube.[15] On the other hand, Heard *et al.* found scalpel-finger-cannula cricothyrotomy preferrable to scalpel-finger-bougie in simulated impalpable anatomy.[25] Nevertheless, needle cricothyrotomy is preferred over surgical cricothyrotomy in the paediatric population until age 12 due to the smaller CTM size and adjacent vascularity.

Since cricothyrotomy is a rare but critical procedure, frequent hands-on practice is also crucial for maintaining proficiency. Simulation training is especially useful for mastering any technique, allowing practitioners to refine their skills when put under pressure.[26] Interdisciplinary training is also on the rise, with many institutions offering collaborative airway management workshops for anaesthesiologists, emergency physicians, and trauma surgeons to practice cricothyrotomy and other emergency airway techniques.[27,28] The DAS guidelines recommend that all airway management personnel be trained in cricothyrotomy to ensure a coordinated and swift response during emergencies.[5]

Cricothyrotomy has a high complication rate as it is performed on patients who have had their airway possibly injured from multiple failed attempts at intubation under very stressful conditions.[15] The complications can be due to problems related to insertion or subsequent ventilation. Open cricothyrotomy is associated with complications of insertion, such as haemorrhage, whereas needle cricothyrotomy is associated with ventilation problems, which are hypercapnia, barotrauma, subcutaneous emphysema, and kinking of the cannula.[14,15] Mid to

longer term complications necessitating further intervention include subglottic stenosis, tracheocutaneous fistula, and tracheomalacia.[14] Ultrasound guidance may reduce the incidence of airway damage.

Guidelines and standardisation

Guidelines are crucial in assisting proper patient management during emergency situations. Although invasive airway access for CICO has existed for many years in these guidelines, the choice of method was not fixed and left to the rescuer.[29,30] Based on the findings of NAP4, the scalpel-bougie method was stated as the eFONA technique of choice by DAS when they updated their guidelines in 2015, which was also mentioned by the Canadian Airway Focus Group a few years later.[23,5,31] As of the time of writing, many of the other major difficult airway management guidelines remain neutral on the cricothyrotomy option, and a few recommend the eFONA method the rescuer is most familiar with.[22,32-34]

We have mentioned regular simulation as a way of becoming proficient when faced with a rare incident such as CICO. A recent review of human factors in anaesthesia described 4 controls involved in improving patient safety and staff well-being, which are design, barriers, mitigations, and the medical practitioners' education and training.[35] It was noted that although the medical practitioners' education and training, such as simulation, are the most frequent measures in the healthcare system, in the long run, these had the least effective control for improving patient safety and staff well-being. Meanwhile, design, which involves managerial tasks such as medical equipment, equipment procurement, drug packaging, and working environment, is the least frequent control in relation to human factors. Yet, when properly implemented, design turned out to be most effective control at improving patient safety, making it as equally important as education and training. In terms of difficult airway management, healthcare design translates into the adequacy and standardisation of proper airway equipment, together with the setup not only within a single department, but also throughout an institution.[23,35] The guidelines on human factors recommend input from human factor experts at the medical equipment procurement stage, together with designing a safe work environment, preferably led by an airway lead.[28,35]

An airway lead, first described in 1996, was one of many recommendations in the NAP 4 report, which states that each anaesthesiology department should have an anaesthesiologist responsible for difficult airway management.[22] The airway lead would head a multidisciplinary hospital airway committee incorporating key departments, namely anaesthesiology, intensive care, emergency

medicine, otorhinolaryngology, and other disciplines such as respiratory therapists and nursing.[28] The responsibilities for hospital leads include promotion of education, audit, standardised hospital-wide airway trolleys, and adherence to current guidelines, which can lead to better and effective difficult airway management.[23,28,35]

When one is faced with CICO, the stress during the event is likely to impair judgement and thought processes. Easily accessible or prominently displayed cognitive aids such as algorithms and checklists, which fall under the barriers category, are also recommended to improve difficult airway management flow and efficacy.[35] Finally, staff well-being should not be forgotten, whereby adequate time is allocated for debriefing following traumatising events such as CICO and eFONA.

Summary

As prevention is better than cure, proper pre-anaesthetic airway assessment may alert the practitioner to potential CICO, leading to adequate preparation and a tailored airway management approach. Poor or absent airway assessment and planning are the 2 main factors contributing to failed airway management.[22] In the anticipated difficult airway, it is worthwhile to identify and mark the surface anatomy of the CTM prior to airway management. While there are a few options of eFONA, when faced with CICO, the fastest and effective rescue method is preferred as the crisis is time-sensitive. At present, the scalpel-bougie method, which utilises minimal steps, is the fastest rescue technique to achieve a definitive airway, as advocated by DAS, while many of the other major guidelines remain neutral regarding cricothyrotomy options. In terms of preparation, we as anaesthesiologists can obtain and retain eFONA skills by attending regular simulation sessions. At the institutional level, easily accessible cognitive aids to assist during emergency and airway equipment standardisation are also essential keys to managing difficult airway scenarios, which ultimately improve patient outcomes.

Declarations

Ethics approval and consent to participate

This is a review article and as such does not require ethical approval and informed consent.

Competing interests
Dr. Muhammad Maaya, Dr. Ina Ismiarti Shariffuddin, and Dr. Shahridan Mohd Fathil serve as Section Editor, Chief Editor, and Deputy Chief Editor, respectively, of Malaysian Journal of Anaesthesiology. They have not been involved in any part of the publication process prior to manuscript acceptance; peer review for this journal is double blind. The remaining authors have no competing interests to declare.

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Unveiling myths of the paediatric larynx: a comprehensive review of anatomical publications and modern insights on cuffed endotracheal tubes

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Abstract

This review critically analyses literature on the anatomy of the paediatric larynx published from 1897 to 2024, with an emphasis on key studies by Fayoux *et al.* and Isa *et al.* These pivotal investigations highlighted significant misconceptions and gaps in knowledge concerning the use of cuffed endotracheal tubes (ETTs) in infants and young children. Despite a comprehensive body of research spanning over a century, essential findings related to laryngeal dimensions and injury mechanisms during intubation were often overlooked or misrepresented in both historical and modern publications. Isa *et al.* conducted a detailed anatomical study using fresh paediatric larynges from autopsies, comparing their results to prior landmark research. Their methods included placing cuffless ETTs and Microcuff tubes (MCTs) in the laryngeal lumen and measuring the placement

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at the vocal cord level. The study demonstrated that the cricoid outlet (CO) is a rigid, circular structure—the narrowest part of the paediatric airway—and that it remains less distensible than the glottis or trachea. Fayoux *et al.*'s earlier work with 150 neonatal specimens confirmed this rigidity and emphasised the potential for significant airway damage when oversized ETTs are forced through the CO. This review highlights that radiological and endoscopic approaches often fail to accurately represent paediatric laryngeal anatomy, leading to clinical practices where inappropriate tube sizes are used. MCTs, despite their popularity, were shown to exceed CO dimensions in infants, risking mucosal damage and scarring. The failure to adopt these anatomical insights into clinical guidelines has led to practices that may compromise patient safety, such as using MCTs in premature infants where the deflated cuff's outer diameter (OD) exceeds CO diameters. Key measurements from Isa *et al.* reaffirm that cuffless ETTs based on ODs, rather than internal diameters, are more appropriate for the paediatric airway. This review urges the inclusion of accurate anatomical data, such as the findings of Fayoux *et al.* and Isa *et al.*, into clinical protocols to prevent airway trauma and improve paediatric intubation outcomes.

Keywords: anatomy, endotracheal tubes, Microcuff tubes, paediatric airway, paediatric larynx

Introduction

Microcuff® (Halyard, Alpharetta, GA, USA) endotracheal tubes (ETTs) are increasingly used in neonatal and paediatric airway management, but a review of paediatric airway anatomy is essential prior to widespread adoption. The cricoid outlet (CO), the narrowest part of the paediatric airway, is where the Microcuff tube's (MCT) cuff resides, raising concerns about mucosal injury, airway oedema, and complications such as subglottic stenosis. This article offers an overview of paediatric airway anatomy and the implications of using MCTs for clinicians.

The anatomy of the paediatric larynx has been studied extensively from 1897 to 2024, with significant contributions from Fayoux *et al.*[1] (Fig. 1) and Isa *et al.*[2] addressing misconceptions regarding cuffed ETTs for infants. A comprehensive understanding of this anatomy is crucial, as key studies on intubation-related injuries are often overlooked, revealing notable gaps in the literature.

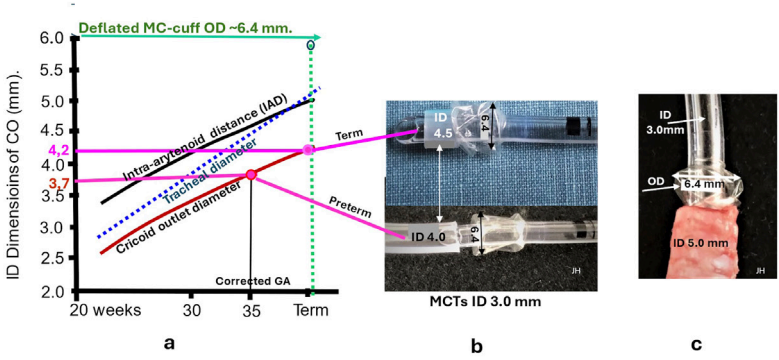

Fig. 1. Dimensions of the larynx and trachea of infants. Relation to MCTs with ID 3.0 mm. *(a)* Airway dimensions of 150 infants, from 35th week of gestation until term neonates.[1] CO diameter of infants (3.7 mm preterm, 4.2 mm term). Too small to permit free passage for deflated MCT cuffs (OD 6.3–6.6 mm) in the trachea (green line in graphic). The IAD is always larger than the CO diameter. Adapted from Fayoux *et al.*[1] *(b)* Deflated MCT cuffs, visibly too large to enter CO equivalents of ID 4.0 and 4.5 mm (premature and term infants, respectively) can be advanced only against marked resistance. *(c)* Deflated MCT cuff too large for animal trachea (ID 5.0 mm, size of 6-month-old infant CO).

Isa *et al.* performed anatomical studies on fresh paediatric larynges to clarify the true configuration of the paediatric airway, comparing their findings with older literature.[2-5] Their research included assessing cuffless ETTs (Vygon Medizintechnik, Germany) and cuffed MCTs to determine their optimal placement in the paediatric larynx and proximal trachea.[2]

Prior beliefs shaped by radiological images lacked backing from endoscopic and anatomical data. Evidence of scarring mechanisms and the absence of stridor in severe airway injuries were neglected.[6-8] Additionally, risks associated with cuff positioning in the CO were noted, particularly in premature infants under 3 kg, despite existing warnings.[9-14]

Fayoux *et al.*'s[1] 2006 study of 150 cadaver larynges confirmed that the CO is rigid and minimally distensible in infants around 35–37 weeks of gestation, suggesting oversized ETTs may compress this outlet.[1] Despite its importance, this study has generally been overlooked in contemporary paediatric airway management discussions (Fig. 1).

Fundamental discrepancies between anatomical findings of the paediatric larynx and misconceptions about MCTs in the literature

Despite extensive anatomical and endoscopic research, misconceptions about the paediatric larynx and MCTs persist. Collaborations among paediatric ENT surgeons and forensic anatomists support the understanding that COs are circular and the narrowest part of the paediatric larynx, as opposed to the glottis, which measures wider in the anteroposterior (A-P) dimension (Table 1).[15-17]

Table 1. Measurements of antero-posterior glottis, cricoid outlet, and proximal trachea in 30 children

Values	Age group (years)		
	0–1	1–3	3–11
Number of children	19	6	5
Glottis A-P (mm)	7.2	10.1	13.7
Glottis IAD (mm)	7.7	9.0	9.5
VC-CO distance (mm)	10.9	13.3	15.2
CO, A-P/transverse (mm)	5.0/5.0	6.4 /6.3	8.3/8.8
Ratio of CO, A-P/transverse	0.99	1.01	0.94 wider than AP
Calibrations (mm)	4.9	6.3	7.9
Trachea, A-P/transverse (mm)	5.1/6.0	7.0 /7.3	8.8 /9.8

A-P: antero-posterior; IAD: inter arytenoid distance; CO: cricoid outlet; VC: vocal cord
Mean values are presented for the 3 different age groups.
Table reproduced from Isa *et al.*[2]

The influential 1951 publication by Eckenhoff led to a preference for cuffless ETTs among paediatric anaesthesiologists, particularly for infants and children up to 8 years of age.1[8] Many institutions maintain this preference, because they are convinced, that cuffless ETTs are less traumatic to the airway in children < 24 months of age. The reliance on cuffless ETTs is rooted in fears of fluid aspiration compared to cuffed tubes particularly with improper cuff placement within the CO that could result in airways trauma. Neglect of the CO's physiological properties has complicated clinical choices.[19]

Emerging literature contrasts essential anatomical insights with the practical considerations of choosing between cuffless ETTs and MCTs. Recent findings indicate that cuffed tubes, when correctly sized and placed, can minimise air leaks, enhance ventilation, and lower re-intubation rates.[17,18,20] This balance is especially significant given ongoing research into long-term outcomes linked to MCT use and the potential risks of subglottic stenosis.

In summary, integrating MCTs into paediatric airway management in children < 24 month of age is never beneficial according to Isa *et al.*'s fact-related findings,[2] yet an in-depth understanding of cricoid anatomy remains crucial.[21-23] The discourse around their application must harmonise historical practices with modern findings, ensuring safe, effective care for our youngest patients. Continued exploration of these discrepancies will be vital as we navigate the evolving landscape of paediatric airway management.

Cuffed intubation evidence and mucosal injury risks

Many institutions adhere to Eckenhoff's principle,[18] claiming that infrequent mucosal injuries occur when cuffless ETTs are carefully inserted. However, the injury patterns differ significantly between cuffless ETTs and cuffed MCTs. Injuries linked to cuffless ETTs predominantly affect the CO, while cuffed MCT injuries can extend from the distal larynx to the upper trachea, necessitating varying surgical interventions. Intubating infants with MCTs can present considerable resistance due to the prominent cuff folds, compounded by the size mismatch between MCTs and the infant cricoid (3.0-mm inner diameter [ID] compared with the infant CO diameter of 5.0 mm), thereby increasing the risk of mucosal injury (Fig. 2).

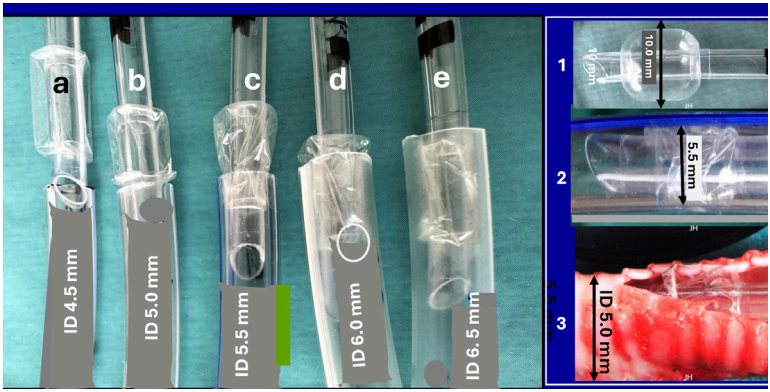

Fig. 2. MCTs too large to enter paediatric airways < 2 years of age. MCTs with ID 3.0 mm, deflated cuffs with ODs ~ 6.4 mm, unable to enter mock COs, diameter of 4.5–5.5 mm, 6.0 mm only with force. *(a, b)* MCTs with ID 3.0 mm, designed for infants. Only the tips of the tubes can enter the artificial infant COs, never the cuffs. *(c)* Only the distal part of MCT cuff with ID 3.0 mm can enter the 5.5-mm diameter CO (child = 18 months of age), but cannot reach the mid-trachea, where it should be. *(d, e)* MCT can enter a 6.0-mm CO (size of 2-year-old child CO) against resistance, but freely first in 6.5-mm CO. *(1)* Inflated MCT with ID 3.0 mm and OD 10 mm. Can never drape freely against the tracheal wall. *(2)* Deflated MCT with ID 3.0 mm, in mock infant trachea. Cuff folds impinge constantly on the mucosa. *(3)* MCT with ID 3.0 mm, deflated cuff in infant-size animal trachea. Opening the anterior wall, the folds of the cuff pop out of the trachea due to the pressure; the cuff folds exert on the tracheal wall.

A pivotal 1997 study by Khine *et al.* popularised cuffed intubation, positing it as a means to reduce intubation attempts in paediatric patients.[24] However, scientific validation was lacking, as the study lacked airway endoscopy. Notably, it did not report intubation rates in neonates, despite advocating for cuffed intubation in this population—a recommendation based on "very low-quality evidence", stated by the Cochrane review.[17] Although cuffed intubation may lessen the number of attempts for clinicians, it simultaneously poses potential risks for paediatric patients due to oversized MCT cuffs.

Fundamental discrepancies in cuffed intubation findings

Khine *et al.* highlighted the growing trend for cuffed intubation, based on the presumption that it would reduce intubation attempts among children.[24] This assumption lacked scientific backing, primarily due to an absence of airway endoscopy data in their study. Although no neonatal intubation rates were documented, cuffed ETTs were nonetheless recommended. Subsequent evaluations by De Orange *et al.* reviewing cuffed versus uncuffed intubation showed similarly low-quality evidence regarding laryngeal mucosa evaluation.[17] Although fewer ETT exchanges occurred in the cuffed group, the absence of endoscopy data meant that documented severe injuries from single MCT insertions remained unaccounted for.

These findings illustrate that the general clinical application of MCTs in young children largely relies on very low-quality evidence. It is crucial that tube selection charts incorporate cuffless ETT options for infants and children, featuring slight variations in outer diameters (ODs) while maintaining similar IDs for enhanced sizing flexibility.

Moreover, depending on stridor as an indicator of airway injury is problematic. While transient subglottic oedema can lead to immediate stridor, more severe, invasive mucosal injuries often manifest no stridor at all, resulting in scarring and stenosis over time. Additionally, Litman's[25] imaging was conducted too high above the CO, as noted by Tucker *et al.*,[26] who provided histological evidence demonstrating that the cricoid is circular at the appropriate level. Tucker's[26] findings dispute Litman's assertion of an oval cricoid,[25] highlighting the necessity of accurate anatomical data in paediatric anaesthesia.

Furthermore, neither Litman *et al.*[25] nor Dalal *et al.*[27] validated the existence of an oval lumen in the paediatric cricoid. Dalal *et al.* performed an endoscopy-based *in vivo* study using a Hopkins lens on 13 children under 2 years, suggesting an oval shape based on illumination observed at the cricoid ring's superior aspect.[27] However, Isa *et al.*[2] rebuffed these findings by applying the same methodology to an A-P section from a fresh infant autopsy specimen (Fig. 3), clarifying that Dalal *et*

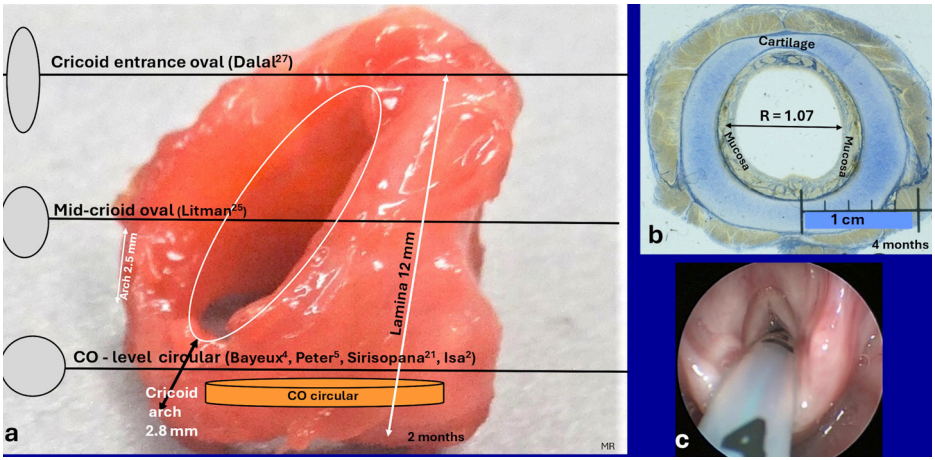

Fig. 3. Cricoid cartilage and CO in infants and small children (fresh and fixed autopsy specimen). *(a)* Oval transection at entrance of cricoid cartilage (Dalal *et al.*[27]) pasted on autopsy specimen (Isa *et al.*[2]). The entrance appears necessarily as an oval, as well as in Litman's MRI findings25). *(b)* Near circular CO (R = 1.07), with well-preserved mucosa by Eckel *et al.* Image courtesy HE Eckel.[23]

al.'s measurements were taken at the entrance of the cricoid cartilage rather than at the circular cricoid, which is located approximately 8 mm lower. This highlights the limitations of indirect imaging techniques in accurately documenting CO levels.

Additionally, Fayoux *et al.*,[1] who studied 300 infant autopsy specimens, was not referenced in Dalal *et al.*'s research,[27] which weakens the validity of their results. Fayoux *et al.* provided critical insights into internal airway diameter at the posterior glottis,[1] illustrating a funnel-shaped narrowing from the glottis to the cricoid outlet—an important detail overlooked by Dalal *et al.*'s claim that a lack of airway sequelae from cuffed tubes has contributed to the reliance on MCTs remains unsupported,[27] especially considering their small sample size and reliance on stridor as an outcome measure instead of post-extubation airway endoscopy.

While MCTs are thought to prevent fluid aspiration into the lungs, studies indicate that MCT cuffs do not effectively block fluid passage into the trachea under various cuff pressures (Fig. 4a-c). Experimental conditions reveal substantial differences in cuff performance between inflated and deflated MCTs, which starkly contrast with industry claims of MCTs providing protection against microaspiration. (Fig. 4d).[28]

Tobias' assertion of a free space behind cuffless ETTs in the "elliptical larynx at or just below the vocal cords" lacks support from any *in vitro* or *in vivo* evidence

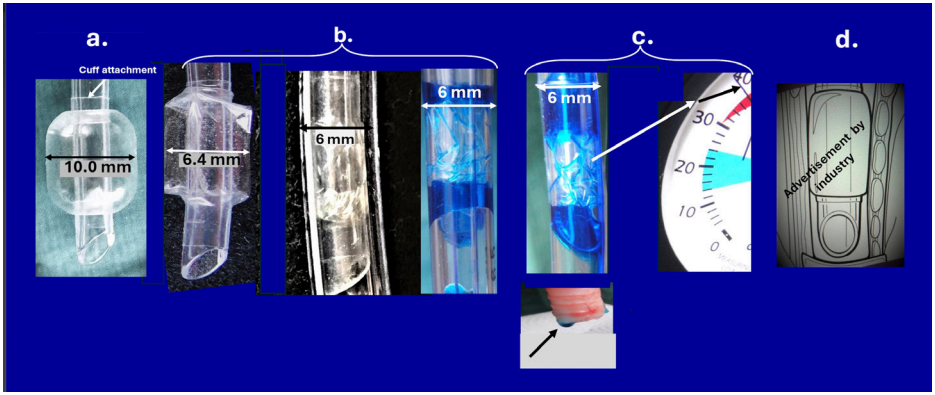

Fig. 4. All ETTs in this image are MCTs with ID 3.0 mm, which are too large for the infant larynx and upper trachea. Cuff wrinkles permit leaking of fluids into the trachea. *(a)* Inflated MCT cuff, OD 10 mm, too large to be placed in infant airway. *(b)* Deflated MCT cuff with OD ~ 6.4 mm. This cuff compressed in a 6.0-mm ID artificial trachea (~ 18-month-old child) shows pronounced impingement of cuff folds on tracheal mucosa. Tinted fluids above the cuff leak constantly into the trachea via capillary spaces between the compressed folds. *(c)* Same situation as *(b)*. Intra-cuff pressure 40 cm H2O. Despite this high intra-cuff pressure, fluids still leak into the trachea. The same occurs in infant-sized animal tracheas (below leaking cuff). *(d)* Drawing of inflated MCT with inflated cuff, supposedly draping the tracheal wall freely and supposedly preventing fluid aspiration (as advertised by industry). This allegation is incorrect!

(Fig. 3c).[15] ETTs can be advanced into the trachea only without a free space behind the ETT, contradicting Tobias' statement. Minimal air leaks anterior of cuffless ETTs do not permit fluid aspiration.[28] Small air leaks anterior to cuffless ETTs do not permit fluid aspiration when a standard positive end-expiratory pressure (PEEP) of approximately 2–4 cm H_2O is applied. These findings challenge Tobias' assertion that MCT cuffs "drape freely" against the paediatric trachea.[15] In reality, MCT cuffs cannot freely conform to the tracheal wall when compressed within the narrower paediatric airway.[28]

Moreover, Tobias misquoted Bayeux's 1897 article, failing to substantiate his claims.[15] The phrase "leak around the tube" is misleading; leaks only occur anteriorly in ETTs (Fig. 3c). A proper spatial representation of the paediatric larynx, which narrows from the glottic level to the cricoid cartilage, is best observed using a Hopkins lens, highlighting the clear distinction between the wide glottis and the circular CO.

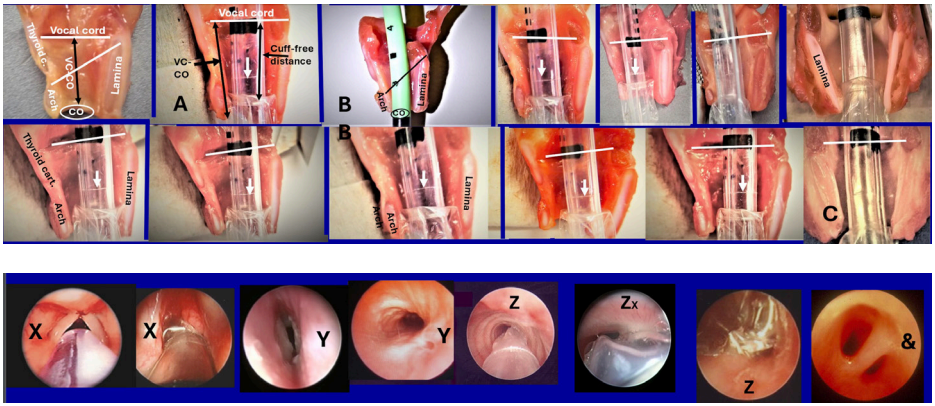

Fig. 5. Position of proximal MCT cuffs within CO, despite depth marks at vocal cord levels. *(a)* MCTs placed on A-P transections of autopsy specimens of the paediatric larynx. Most important are the findings that all MCT cuffs lie with the proximal part within the CO instead in the mid-trachea, where they should be *(A)*. The cause is the longer VC-CO distance compared to the cuff-free distance on the MCT-shaft, which is too short, never directly measured before the Isa investigation2. This is an intrinsic deficit of all MCTs. Cuffless ETTs of adequate size impinge only minimally on the airway mucosa *(B)* even when moving. Particularly dangerous is the position of the sharp attachment of the cuff close to the CO *(C)*.
(b) Endoscopic evidence of injuries by MCT intubation (admissions to paediatric ENT Centre, Children's Hospital Cologne, Germany). Endoscopic findings controlling position of MCTs before and after extubation, and during mechanical ventilation. MCTs are regularly misplaced into the larynx *(X)*, a dangerous position relating to airway injury. Significant tracheal injuries after short- and long-term intubation *(Y)*. Evidence of tracheal injury during mechanical ventilation, difficult to get, but extremely important. There was no overinflation of cuffs *(Z)*. Years-old scar after cuffed intubation *(&)*. Accidental finding.

Isa *et al.*[2] first illustrated this anatomy, correcting the misconception that the vocal cords are the narrowest part of the paediatric larynx; they are, in fact, distensible. During autopsies, the cords often appear nearly closed (cadaveric position), yet they remain distensible in both *in vitro* and *in vivo* settings.[26] In vivo, vocal cords can close tightly during laryngospasm but also distend widely during deep breaths, refuting claims that the paediatric glottis is the narrowest portion of the airway.

Publications suggesting an oval shape for paediatric cricoid cartilage are based on radiologic imaging conducted under neuromuscular blockade or deep sedation, which misrepresents natural anatomy. While vocal cords may appear narrow under these conditions, they are typically distensible. Appropriately sized cuffless ETTs can be effectively used during intubation, as shown in various anatomical investigations.[24-26]

Isa *et al.* first identified the flawed relationship between MCT cuffs and paediatric larynx anatomy in a study involving 30 autopsy specimens.[2] They found that MCT cuffs are often positioned too deep within the distal larynx, heightening the risk of mucosal damage from cuff folds. In 23 of the specimens examined, MCT cuffs were found lodged deep within the CO, failing to reach the mid-trachea as intended (Fig. 5a).

Despite these important findings, there have been no improvements in MCT design. One potential way forward involves comparing cuffless tubes with MCTs of the same internal diameter (3.0 mm) to assess performance during transected autopsy larynges. Differences in ODs could be further evaluated by manipulating the tubes within the larynx during autopsy and *in vivo* trials. Cuffless ETTs allow for minimal mucosal impingement during movement or turning.[29,30]

Cuffless ETTs minimise mucosal impingement during head movement, whereas mispositioned MCTs continuously exert pressure on the CO mucosa. A noted paediatric ENT surgeon remarked that the narrow CO effectively acts as a "cuff" for cuffless tubes, leading to reduced contact and decreased granuloma formation. In contrast, MCT cuffs compress against the distal larynx, increasing the risk of mucosal injury, particularly when infants move (Fig. 5a).

Greany *et al.* conducted endoscopies 6 months post-intubation in nearly 300 infants who were intubated with 3.0-mm internal diameter MCTs, which had deflated ODs of approximately 6.3 mm.[31] This is concerning, considering that Isa *et al.* found CO diameters in neonates and infants up to 10 months to be approximately 5 mm, with tracheal diameters ranging from 5.1 mm to 5.4 mm.[2] An MCT cuff of ~ 6.3 mm is too large for the paediatric airway, risking mucosal compression, especially with prolonged cuff presence. Parents of children with airway injuries are often hesitant to return to the same medical facility where an injury occurred. (Fig 5b).

Endoscopies performed months later can miss prior airborne injuries, as vocal function damage can be undetectable at this stage. Acute injuries such as ulcers may heal well and can be absent during later examinations. Early airway endoscopy following exposure to oversized cuffs is vital for prompt injury treatment and preservation of vocal function.

Greany *et al.*'s findings lack scientific validation for MCT use in children[31] and clash with anatomical evidence by Isa *et al.*[2] and Fayoux *et al.*[1] The chronic misplacement of MCT cuffs in the distal larynx, due to insufficient cuff-free distance on the tube shaft, heightens the risk of significant mucosal injury.[31,32] Improved MCT design is critical for enhancing airway safety for paediatric patients.

Despite existing evidence, 3.0-mm ID MCTs with approximately 6.3-mm cuff ODs are still recommended for infants up to 8 months.[14] Conversely, a 3.5-mm ID MCT intended for children aged 8 to 24 months, which has a cuff OD of nearly 7.8 mm and a typical CO diameter of 5.5 mm, has proven excessively large in experimental studies.[1,2] Findings show that MCT cuffs often do not sit in the mid-trachea but remain in the CO. Literature advises that "a cuffed paediatric tracheal tube should have adequate depth markings and not be inflated in the subglottic region." In practice, however, depth markings generally denote placement at the vocal cord level, yet MCT cuffs frequently end up improperly positioned in the CO (Fig. 5b).[33,34] This misplacement has not been reliably assessed through airway endoscopy.

To assess the effects of MCT cuff folds on the tracheal mucosa, a 2.0-mm OD Hopkins lens was placed alongside an MCT shaft to observe the deflated cuff during mechanical ventilation. The cuff folds scraped the mucosa, resulting in visible damage, which can only be thoroughly evaluated through endoscopy. Unfortunately, late endoscopies may miss critical injury assessments necessary for effective treatment.

The ongoing improper positioning of MCT cuffs too close to the CO necessitates design improvements for better airway safety in paediatric patients.[33,34] The impact of 3.0-mm ID MCT cuffs on infant laryngeal mucosa can be clearly documented using high-quality infant manikins during intubation. The effects of the cuff folds on the glottis are observable during both intubation and extubation.

Both *in vitro* and *in vivo* evidence—such as intubation of manikins and real infants—highlights the mucosal effects of cuff folds. Given that all MCT cuffs remain positioned within the CO in children studied by Isa *et al.*,[2] these findings should urge physicians to reevaluate their use of MCTs for tracheal intubation in premature and infant patients, and manufacturers should reconsider their guidelines for recommending 3.0-mm ID MCTs for this population.

Several authors have proposed modifications to MCTs to improve their fit in the airways of infants and small children. Jordi-Ritz *et al.*[34] found that MCT cuffs can move approximately 7 mm up and 5 mm down the airway during movement or repositioning, potentially causing injuries to the CO.[34] Isa *et al.*,[2] along with Kemper *et al.*[35] and Moehrlen *et al.*,[36] recognised the issue of oversized MCT cuffs, suggesting that repositioning depth markings further up the MCT shafts and shortening the cuff's length and width could ensure proper placement in the mid-trachea while preventing right mainstem bronchus intubation. Despite the reasonableness of these design changes, they have not been implemented. Misleading advertisements still claim that "MCTs are specifically designed with correct anatomical depth markings," which is inaccurate, as demonstrated in desktop experiments (Fig. 4).

A major disadvantage of MCTs is the inadequacy of the cuff-free distance on their shafts. Although Isa *et al.*'s findings2 received limited attention, one editorial[35] correctly stated that the circular CO is the narrowest rigid point of the paediatric airway but overlooked the issue of improper cuff positioning. It failed to address the significant concern raised by Isa *et al.* regarding MCT cuffs being inadequately positioned in the distal larynx.

Do Isa *et al.*'s findings impact on daily paediatric intubation with MCTs?
Yes, they document the harmful effects of improperly positioned cuffs on the mucosa of the paediatric larynx and trachea. Scientific articles that fail to consider CO dimensions, including glottic length and the OD of deflated MCT cuffs, should be viewed sceptically, as they neglect the well-being of children.[37]

Airway endoscopy is vital for detecting trauma, even after what seems like uneventful intubations. An insightful editorial[38] highlighted this, noting that many anaesthesiologists are surprised by post-intubation findings, indicating that even minor injuries may occur. This underscores the ineffectiveness of late airway endoscopies, such as those conducted in Greany *et al.*, in evaluating airway injury 6 months after intubation with MCT cuffs.[31]

Case-control studies with large participant numbers can help answer unresolved questions.[39] A study was conducted to assess the safety of MCTs for long-term airway outcomes in children under 2 years, involving 2,200 participants from 24 institutions.[39] The results showed similar outcomes between groups in terms of post-extubation stridor, intubation attempts, and effective sealing against aspiration.

However, the study had notable limitations. It provided no new insights compared to prior research. Physicians were allowed to use cuffless ETTs at their discretion without specifying tube ODs, which vary greatly, leaving the impact on airway mucosa unaddressed. Additionally, the ODs of deflated MCT cuffs—a key factor in airway injury—were not discussed. The assertion that MCT cuffs conform freely to tracheal walls is technically inaccurate, as demonstrated by Isa *et al.* The study's industry funding raised concerns about bias and contributed to an unnecessarily large sample size. The Cochrane review[17] noted this issue and highlighted the absence of post-anaesthesia airway endoscopy, a consistent limitation in previous studies.

Importantly, the study did not address potential airway injuries from MCT cuffs, providing no compelling argument for their advantage. Despite the large sample, it added limited scientific value and was rated as very low-quality evidence.[17]

The assertion by Weiss *et al.*[32] that depth markings on MCT shafts assist in positioning endotracheal tubes in children is contradicted by Isa *et al.*'s research.[2] Stridor, a symptom of airway injury, is not an effective indicator of airway obstruction post-intubation, as it usually occurs only when over 50% of the airway lumen is blocked; severe mucosal ulcers may not cause stridor after extubation. Damaged tissue can heal, forming scar tissue that might only become apparent later (Fig. 5b), emphasizing the importance of airway endoscopy for the timely detection of post-anaesthesia airway injuries.

Dariya *et al.* investigated cuffed versus uncuffed ETTs in neonates, including 69 subjects.[40] Their results showed very low evidence of differences between the 2 groups, and potential bias was evident. The absence of endoscopy results limited the evaluation of airway injuries, thus making their review unhelpful in determining the preference for cuffed or uncuffed tubes in neonates.

Bernet *et al.* found that 3.0-mm ID MCTs used in premature infants under 3 kg led to significant injuries requiring invasive treatment, cautioning against the use of MCTs in these patients.[41] Additionally, they noted that post-extubation stridor could be due to oversized cuff wrinkles, aligning with Isa *et al.*'s anatomical descriptions.[2] Bernet *et al.* recommended relying on formulas for cuffless tube insertion to ensure safe ETT placement in infants, rather than using cuffed tubes.[41]

A retrospective study raised further safety concerns regarding MCTs for premature infants, analysing 29 neonates intubated with MCTs and 21 with uncuffed ETTs for up to 20 days.[42] It found that the post-extubation stridor rate was significantly higher in the MCT group (17.2%) versus the uncuffed group (7.5%), reaching 19.2% in infants under 3 kg. Although no endoscopy was performed, the symptoms were deemed reliable indicators. These findings underscore the necessity for larger studies with post-extubation airway endoscopies following extended intubation.

There is no scientific basis for using MCTs in premature infants and children under 2 years of age, despite fewer ETT exchanges. A redesign of cuffed ETTs for this demographic group is critical, as Isa *et al.*'s findings raise alarm about the care of premature infants up to 24 months using 3.0-mm ID MCTs, which necessitate compression to fit their airways.[2] One alternative proposed by C. Coté from Harvard University is to revert to cuffless intubation for infants, a practice already adopted by many institutions, including those in Europe and the Children's Hospital in Cologne, complemented by airway endoscopy and the use of tube selection charts. These charts account for both IDs and ODs (measured in French sizes), significantly affecting the risk of airway injury. Since 1955, tube selection charts have guided the careful intubation of cuffless ETTs in paediatric patients, offering slightly smaller and larger tube options with the same ID. This method minimises the occurrence

of “multiple attempts at intubation,” a practice that should be avoided whenever possible. These charts, however, need to be adjusted for different population sizes.

Using cuffless ETTs until the end of the second year is rational and effective. This technique, along with precautionary measures such as small amounts of PEEP to limit fluid aspiration, has been successfully practiced for many years. There is an increasing preference for intubating infants with precisely selected cuffless ETTs rather than MCTs with oversized cuffs (Figs. 4, 5).

A visual comparison in Figure 5a demonstrates the notable difference between the OD of a smooth cuffless ETT and the bulging cuff of an MCT, both with the same ID. The oversized OD of the MCT cuff and the compressed folds entering the glottis illustrate that the MCT cuff does not drape freely in the upper paediatric airway. Instead, the compressed folds consistently press against the airway mucosa, exerting unknown pressures that may lead to potential injuries.

This evidence underscores the urgent need for a redesign of MCTs. The cost discrepancy is significant, with a single cuffless ETT costing approximately €1.90 in Germany compared to nearly €15.00 for an MCT.

Recent airway management guidelines have emerged, though many of their recommendations are based on limited or low-quality evidence.[43,44] These guidelines reflect historical data and may not adequately address future requirements. While they correctly state that insufficient data supports the routine use of cuffed ETTs in children under 3 kg due to restrictive ODs, they erroneously claim that cuffed ETTs are safe for infants over 3 kg.[45] This contradicts findings from Fayoux *et al.*[1] and Isa *et al.*,[2] which reveal that the ODs of deflated MCT cuffs (~ 6.4 mm) are too large for the average infant cricoid (mean 5.0 mm).

The recommendation to adhere strictly to manufacturer instructions appears biased, with important discussions about the role of post-anaesthesia airway endoscopy in detecting airway injuries after intubation missing from the guidelines. Ponde *et al.*[45] emphasised these inaccuracies, asserting that only randomised studies independent of industry funding, which also encompass endoscopic evaluations, can yield dependable data for managing the airways of premature infants and small children.[45]

At the 18th Asian Society of Paediatric Anaesthesiologists (ASPA) meeting in 2022, several lectures and workshops emphasised significant findings from Isa *et al.*[2] Experienced paediatric anaesthesiologists recognised that the cricoid is the narrowest, circular, and rigid part of the paediatric larynx prior to school age.

Isa *et al.*'s discovery that proximal MCT cuffs were either within or very close to the CO in all studied autopsy specimens[2] stimulated substantial discussions regarding the implications for intubation practices, significantly influencing this article's creation.

A review of references for paediatric endotracheal intubation reveals that most studies lack airway endoscopy, insights from ENT surgeons, and consultations with paediatric anatomists. This absence impedes real-time documentation of mucosal injuries and delays timely treatment for airway trauma.

Critiques of this study are guided by the Cochrane Handbook for Systematic Reviews,[43] emphasizing that valid, historical publications should not be overlooked. References must originate from primary sources to avoid secondary citations. Additionally, studies with disproportionately large participant pools that yield no new data possess limited scientific value, and industry-funded studies frequently demonstrate bias.

This article uses visual aids and simple experiments to substantiate its claims, making replication straightforward for readers.

Declarations

Ethics approval and consent to participate

This is a review article and as such does not require ethical approval nor informed consent.

Competing interests

None to declare

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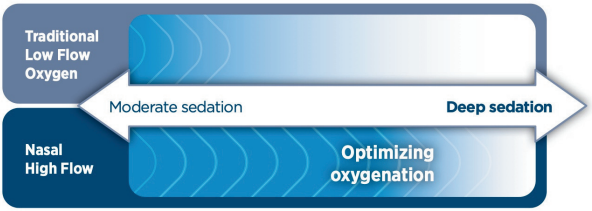
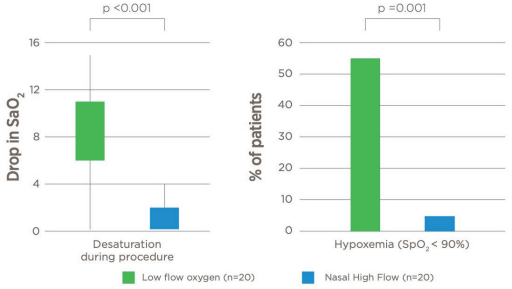


Irfan et al. 2021
Bronchoscopy

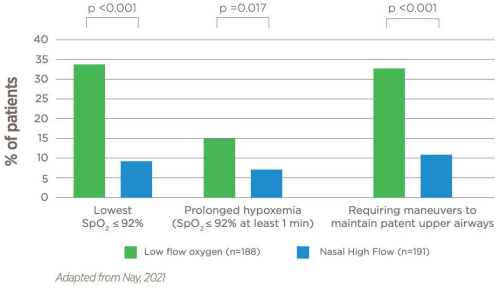
A single-center RCT by Irfan et al.[5] showed that Nasal High Flow reduced the drop in oxygen saturation and the incidence of O_2 desaturation <90% compared to low flow nasal cannula oxygen in patients undergoing EBUS-TBNA bronchoscopy under midazolam and alfentanil sedation.



Adapted from Irfan, 2021

Nay et al. 2021
GI endoscopy

A multi-center RCT by Nay et al.[6] showed that Nasal High Flow reduced the incidence of O_2 desaturation ≤95% and the need for airway maneuvers compared to low flow oxygen in patients at risk of hypoxemia undergoing gastrointestinal endoscopy under propofol sedation.



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Awake cardiopulmonary bypass under neuraxial anaesthesia for elective posterior mediastinal mass excision

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Abstract

A pre-existing compression of the airways and/or great vessels secondary to a large mediastinal mass, risks respiratory and haemodynamic compromise in which complete airway obstruction and cardiovascular collapse are anticipated. Most of the literature routinely recommends having cardiopulmonary bypass (CPB) on stand-by with the perfusionists on ready mode and machine primed. Establishment of awake CPB for mediastinal tumour resection has been scarcely reported, with most being done under local anaesthesia (LA). We report a case of 65-year-old woman with a large, asymptomatic, right posterior mediastinal tumour scheduled for elective surgical excision in our centre. The surgery in the previous hospital, which had no CPB service, was postponed after the patient experienced haemodynamic and ventilatory events. In view of the events, we opted for early initiation of CPB prior to general anaesthesia to avoid delays in activating stand-by CPB. The cardiothoracic surgical team specifically wanted a smooth femoro-femoral cannulation, hence neuraxial anaesthesia was performed. This unconventional approach of awake CPB under neuraxial block provides a favourable cannulation site compared to a field infiltrated with LA, anaesthesia maintenance if cannulation is required contralaterally, and predictable analgesia for the awake patient throughout the procedure.

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Keywords: cardiopulmonary bypass, neuraxial anaesthesia, posterior mediastinal mass

Introduction

Anaesthetic management for mediastinal mass is known to be challenging, predominantly due to concerns of respiratory and haemodynamic stability. Haemodynamic perturbation, inability to ventilate, or both, could ensue from induction of general anaesthesia (GA) in cases involving a large mediastinal mass. Awake cardiopulmonary bypass (CPB) provides a method to control both the airway and haemodynamics. Most of the literature merely recommends having CPB on stand-by with the perfusionists on ready-mode and machine primed. On the other hand, our case illustrates the initiation of CPB under neuraxial anaesthesia prior to mediastinal mass resection.

Case report

A 65-year-old woman with underlying diabetes mellitus, hypertension, and bronchial asthma was referred to our facility for further management of her mediastinal mass. Three months prior to this admission, she presented to the primary centre with joint pain in the right knee requiring ward admission. A large right mediastinal mass was inadvertently found on the routine chest X-ray. Upon further questioning, she was asymptomatic and denied any compression symptoms. Initial contrast enhanced computed tomography (CECT) showed a right posterior mediastinal mass compressing the airway. Ultrasound-guided biopsy subsequently revealed a benign spindle cell tumour.

The primary attending hospital scheduled this case for a tumour excision. However, the patient developed superior vena cava obstruction after gas induction. The team proceeded with awake fibreoptic intubation via flexometallic endotracheal tube, but was unable maintain ventilation. Therefore, the patient was extubated and the surgery postponed.

The case was subsequently referred to our unit. Repeat CECT (Fig. 1) showed mechanical compression from the right thoracic mass seen from T3 extending progressively towards the carina until the right main bronchus, as well as compression of the right brachiocephalic vein. Magnetic resonance showed a large right posterior mediastinal mass with local effect, erosion of T3 vertebral body,

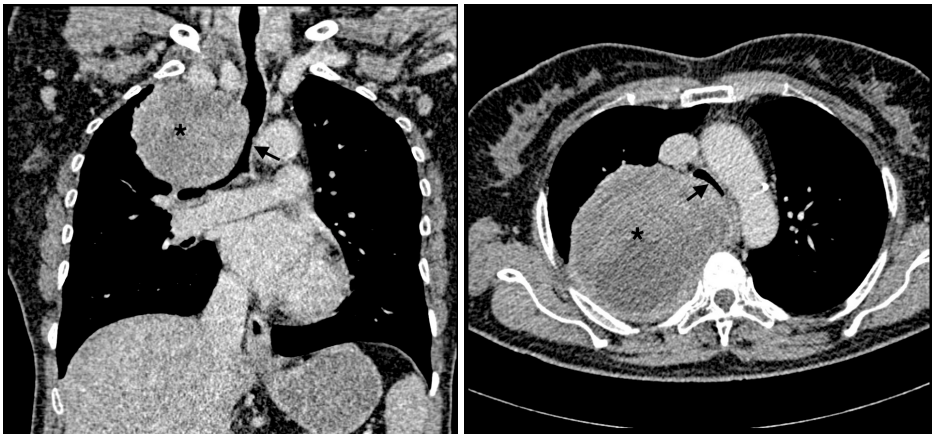

Fig. 1. (A) Contrast-enhanced CT of the thorax in coronal plane showing large heterogeneously enhancing mass (*) occupying upper thorax compressing the trachea, carina, and right main bronchus (arrow). *(B)* Contrast-enhanced CT of the thorax in axial plane showing large heterogeneously enhancing mass (*) occupying the upper thorax compressing the trachea (arrow).

and intraspinal extension of the mass into the right aspect of the spinal canal with minimal compression of the spinal cord and no cord involvement or myelopathy.

Pulmonary function test results were 46% for forced expiratory volume (FEV1), 45% for forced vital capacity (FVC), and 84% for FEV1/FVC. Echocardiography showed left ventricular ejection fraction of 58%, grade 1 diastolic dysfunction, and trivial regurgitation of mitral, tricuspid and pulmonary valves. An excision of posterior mediastinal tumour was planned, and consent for high-risk surgery and anaesthetic was obtained. The multidisciplinary team decided to initiate CPB prior to GA to avoid delays in activating stand-by CPB.

No premedication was administered to the patient. In the operation theatre, standard American Society of Anesthesiologists (ASA) monitors were placed; 18-G intravenous and 20-G arterial cannulas were secured in the left brachial vein and right radial artery, respectively. Neuraxial anaesthesia with 10 mg of hyperbaric bupivacaine was injected intrathecally in L4/ L5 using 27-G Pencan (B. Braun, Melsungen, Germany) in a sitting position. A central venous catheter was then inserted in the left femoral vein under ultrasound guidance. Subsequently, cannulation in the right femoral vein and right femoral artery was performed via open technique by the surgeon. All procedures were smooth and single attempt. The patient was preoxygenated with 100% oxygen while a three-quarter flow of normothermic CPB was initiated after full heparinisation of 20,000 IU (400 IU/ kg) was administered, achieving an activated clotting time (ACT) of 424 seconds,

Fig. 2. (A) Fibreoptic bronchoscopy image post-intubation shows slit-like opening of the right main bronchus. *(B)* Fibreoptic bronchoscopy image of bronchial lumen of left DLT (black arrow) and right main bronchus (red arrow) collapsed during positive pressure ventilation.

3.5 times the baseline ACT value. Right after the onset of CPB, fentanyl 100 µg, propofol 50 mg, midazolam 2 mg, and suxamethonium 50 mg were administered intravenously. Intubation was achieved on the first attempt using a C-MAC video laryngoscope (KARL STORZ SE, Tuttlingen, Germany) with a double lumen endotracheal tube. Bronchoscopy was performed to ensure proper placement of the endotracheal tube and revealed external compression from the end of the tracheal lumen extending towards the right main bronchus and appearing a as slit-like opening of the trachea (Fig. 2). Conversion to full flow CPB was established after the monitor showed hypotension and sustained 20% reduction from baseline cerebral oximetry value. Mechanical ventilation was subsequently terminated.

Intraoperatively, anaesthesia was maintained with sevoflurane 1.5–1.7% minimum alveolar concentration of 0.9 from the CPB and Target-Controlled Infusion remifentanil 2-3 ng/ml. Haemodynamics were supported with low infusion of noradrenaline to achieve a mean arterial pressure target > 65 mmHg. Surgery started when oxygenation and haemodynamics were well controlled. A firm, well-defined and well-encapsulated posterior mediastinal mass (9 cm x 11 cm) was excised. Subsequently, the patient was able to be separated from the CPB (bypass time 172 minutes) with low-dose noradrenaline support reversed with protamine.

After a few minutes, the patient required increasing inotropic support. The surgeon noted bleeding at the spinal venous plexus involving the foramen. Haemostasis was attempted but could not contain the bleeding. The patient had pulseless electrical activity with intermittent ventricular fibrillation. Internal and external defibrillation as well as cardiac massage were applied for more than 40 minutes. Catastrophic bleeding ensued and after full resuscitation, we decided to proceed no further.

Discussion

Cases of large mediastinal tumour present significant risks in maintaining a patent airway. It is not rare to encounter total occlusion of the airway after induction of GA in such cases. Airway obstruction has been recognized to be due to the loss of the tethering effect of the expanded lungs on the airways from a reduction of the inspiratory muscle tone as well as the lung volume. Neurogenic tumours constitute 67% of posterior mediastinal mass cases,[1] which seldom lead to airway problems. Meanwhile, we had a distinct scenario for our patient. She was asymptomatic preoperatively but developed superior vena cava obstruction after gas induction and ventilation difficulties upon left lateral position during her first elective surgery. Compression of the airway and intrathoracic structures in a patient with mediastinal mass may depend on patient position; thus, it is pivotal to identify the most comfortable position for the patient preoperatively.[2]

The literature contains limited reports on the prophylactic use of CPB in posterior mediastinal mass cases, most of which typically propose having a stand-by CPB during surgery. Elective CPB for non-cardiac cases has been reported in head and neck surgery as well as tracheal resection,[3,4] but only a few cases have been reported exclusively for airway and haemodynamic management.[5,6] Surman *et al.* suggested considering CBP for high-risk, non-cardiac, surgical cases involving the thorax and great vessels, as it allows for haemodynamic stabilisation when unexpected impediments occur.[6] CPB allows the surgical team safe sternal entry and aids mass resection while preserving haemodynamic stability.[5,7]

We successfully performed a neuraxial anaesthesia and initiated an awake CPB for a patient with a large posterior mediastinal mass. Anticipating ventilatory difficulty, we opted to initiate CPB before GA induction and for the surgery to be done in supine position. Neuraxial anaesthesia in patients undergoing heparinisation for CPB is still a matter of debate. It is pivotal to weight the relative risk and benefit of neuraxial anaesthesia in such patient.

A prospective, randomised study concluded that the time maintained in sitting position after spinal anaesthesia has considerable effect on the localisation of the drug along with lesser sensory and motor blockade and ensures safe haemodynamics.[8] Spinal block was chosen over one-sided regional anaesthesia to block the femoral bilaterally in anticipation of difficult cannulation on one side. After the intrathecal injection, we confirmed the distribution of the block have reached the L1 and L2 dermatomes, covering the puncture site at the femoral area before proceeding with the cannulation.

Our patient received 10 mg of hyperbaric bupivacaine intrathecally over L4/L5 to ease femoro-femoral cannulation by the surgeon. The rationale of the subarachnoid block is to avoid local tissue and structural distortion after LA infiltration in order to ensure a predictable analgesia for presurgical femoro-femoral cannulation and avoid difficult cannulation. Furthermore, this technique provides comfort to the awake patient throughout the procedure as adequate anaesthesia can be maintained in case of contralateral cannulation.

Neuraxial block can be performed in sitting or lateral position; hence, it is suitable for patients with posterior mediastinal mass since they are rarely symptomatic in sitting position. In addition, subarachnoid block is a common procedure with which all anaesthetists are familiar and does not require the level of practice required for regional block. Neuraxial block possess well-known contraindications and limitation such as in uncorrected hypovolemia, increased intracranial pressure, fixed cardiac output states, coagulopathy and sepsis. Consequently, this technique might not be appropriate for emergency case where patient is hemodynamically unstable.

A review has recommended certain precautions to minimise the risk of neuraxial block as well as heparinisation in CPB, where time from instrumentation to systemic heparinisation should exceed 60 minutes.[9] Weiner *et al.* found no complications related to neuraxial anaesthesia in a series of 714 patients undergoing surgery for congenital heart disease using CPB, including 466 patients in whom the interval from neuraxial anaesthesia to full heparinisation was less than 1 hour.[10] As per our planning, heparinisation was performed 60 minutes after spinal puncture. To avoid or minimise the risk of complications from neuraxial anaesthesia, such as spinal haematoma, we planned for GA induction an hour after the spinal puncture. Therefore, the surgeon was not in a rush to cannulate and preparation for general anaesthesia and CPB initiation were not hurried.

We administered 400 IU/kg (20,000 IU) heparin after the femoral cannulation which was well beyond 1 hour from the spinal puncture. The CPB, subsequently, was initiated early prior to induction of GA. This is therefore, to mitigate the potential hemodynamic and airway compromise during GA. The CPB was escalated to full flow when we detected the hemodynamic attenuation after GA. Weaning from CPB started as soon as the mediastinal mass was excised and later CPB terminated while the patient was on low-dose inotropic support. Unfortunately, catastrophic bleeding from spinal venous plexus occurred. Going back on CPB was an option; however, we decided against it as the surgeon was worried about re-heparinising the patient, which could have worsened the ongoing bleeding.

Although the initiation of CPB under neuraxial anaesthesia was successful, the outcome of the surgery was not. For similar posterior mediastinal mass cases, we strongly recommend a proper multidisciplinary team discussion involving the radiologist and spine surgeon to discuss the feasibility of preoperative prophylactic embolization of the spinal venous plexus. Using intraoperative cell salvage and delaying CPB termination could increase the chance for successful resuscitation in anticipation of delayed intraoperative bleeding. All in all, our approach of CPB under neuraxial anaesthesia effectively provided adequate and guaranteed analgesia during peripheral bypass cannulation for awake CPB. We therefore recommend this method if early initiation of CPB is considered.

Declarations

The patient consented to the publication of the clinical data and images contained in this case report.

Competing interests
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Contralateral pneumothorax: the hidden culprit in failed oxygenation during non-intubated video-assisted thoracoscopic surgery

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Abstract

The occurrence of contralateral pneumothorax during non-intubated video-assisted thoracoscopic surgery (NiVATS) is rare and difficult to diagnose intraoperatively due to its non-specific clinical presentations. Temporary desaturation is not uncommon in NiVATS. This report highlights a case where maintaining oxygenation proved challenging despite various remedial interventions, ranging from use of high-flow oxygen delivery to manual jet ventilation via Cook airway exchange catheter during right NiVATS for distal tracheal mass resection and reconstruction. Intermittent cross-field ventilation was employed during tumour removal and tracheal anastomosis to maintain oxygenation. Postoperative chest X-ray revealed the reason for oxygenation failure: pneumothorax on the left side. The left-side chest tube was not inserted because the patient remained asymptomatic post-extubation. The patient was discharged well on postoperative day 8. Repeated bronchoscopy at 1-month post-surgery revealed intact anastomosis. Prompt diagnosis of pneumothorax in high-risk surgeries and contingency airway plans are imperative in managing patients undergoing NiVATS to prevent airway mishaps.

Keywords: distal tracheal mass resection, non-intubated video-assisted thoracoscopic surgery, oxygenation, pneumothorax, reconstruction

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Introduction

Spontaneous ventilation in non-intubated video-assisted thoracoscopic surgery (NiVATS) has garnered increasing interest from anaesthesiologists, as it has been shown to result in fewer perioperative side effects compared to general anaesthesia and tracheal intubation. The technique is carried out with minimal or no muscle relaxants to maintain spontaneous respiration, which hastens recovery after surgery. Surgeons also favour this approach because it simplifies, accelerates, and tidies end-to-end tracheal anastomosis without the interference of the tracheal tube.[1,2]

NiVATS poses its own set of challenges to the anaesthesiologist: major bleeding, severe hypoxaemia, hypercapnia, excessive mediastinal and diaphragmatic shifts, and inadequate lung collapse and coughing. It is therefore crucial that the anaesthesiologist has ample experience to overcome these concerns accordingly.[2,3]

This report highlights a case of difficult oxygenation during right NiVATS for distal tracheal mass resection and reconstruction. Maintaining oxygenation proved a challenge despite various interventions, ranging from the use of high-flow oxygen delivery to manual jet ventilation via Cook airway exchange catheter. Ultimately, a postoperative chest X-ray revealed the reason for oxygenation failure: left-side pneumothorax.

Case presentation

Written informed consent was obtained from the patient. A 58-year-old female with a body mass index of 18 kg/m^2, known case of bronchial asthma and breast cancer, presented with a 6-month history of progressively worsening shortness of breath and cough. Physical examination revealed a prolonged expiratory phase upon auscultation. A computed topography (CT) scan of the chest confirmed the presence of a distal tracheal lesion located 1 cm from the carina (Fig. 1a). Bronchoscopy identified a 1-cm tumour on the lateral wall of the distal trachea obstructing 90% of the tracheal lumen (Fig. 1b). Based on the distal lesion causing 90% of tracheal obstruction, NiVATS with supraglottic airway (SGA) device was planned for the patient. Our initial airway plan for all phases of the surgery was to maintain the patient's spontaneous ventilation with high-flow oxygen 60 L/min through SGA. The surgical phases included anaesthesia induction, tracheal mobilisation and dissection, tracheal transection, tracheal anastomosis, and closure (Fig. 2).

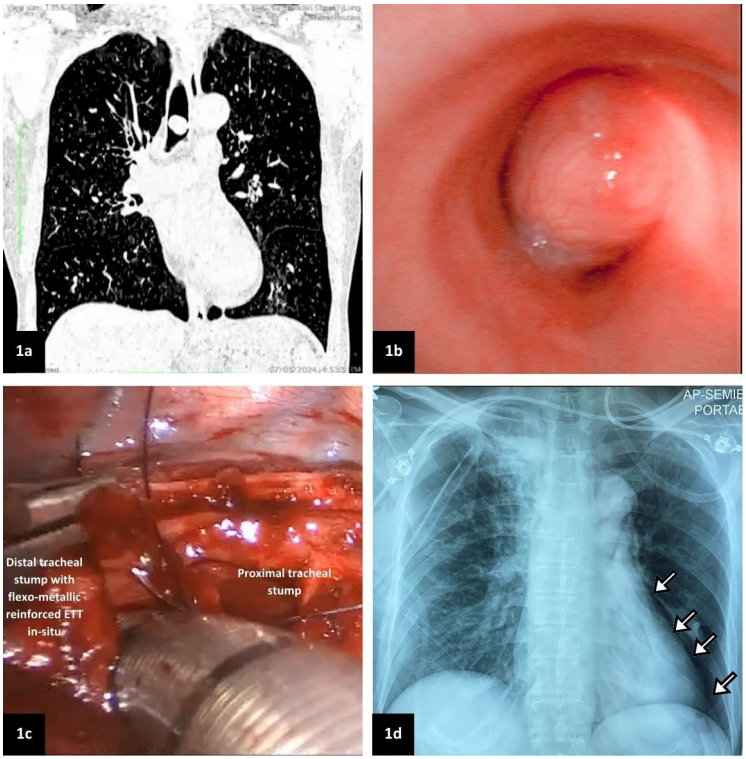

Fig. 1. (a) Computed topography image showing a pedunculated tracheal mass above the carina. *(b)* Bronchoscopic view of the tracheal mass obstructing the trachea above the carina. *(c)* Thoracoscopic view of the distal tracheal stump intubated with an flexo-metallic reinforced endotracheal tube (ETT) during cross-field ventilation. *(d)* Postoperative chest X-ray revealing a left pneumothorax (white arrow). The right chest tube is *in situ*.

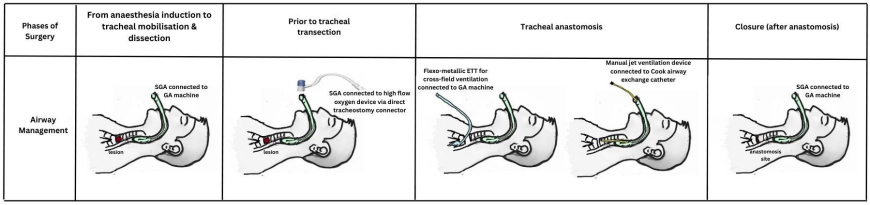

Fig. 2. Diagram illustrating the airway device used in each phase of the surgery. SGA: supraglottic airway; GA: general anaesthesia; ETT: endotracheal tube

Prior to anaesthesia induction, standard vital sign monitoring (non-invasive blood pressure, pulse rate, saturation oxygenation and capnography) was applied in the supine position and the patient was pre-oxygenated with 100% oxygen. Total intravenous anaesthesia was achieved using target-controlled infusions of propofol 1% and remifentanil using the Schnider and Minto models, respectively, aiming for a bispectral index reading between 45 to 60. A size 3 i-gel® SGA device (Intersurgical Ltd., Pabradė, Lithuania) was inserted after induction, and spontaneous ventilation was maintained with 100% oxygen at 4 L/min via a general anaesthetic (GA) machine (GE Aestiva®5, Datex Ohmeda). Target-controlled infusions of propofol 1% and remifentanil were titrated to achieve spontaneous a respiratory rate less than 10 breaths/min. An arterial line for invasive monitoring and blood gas sampling was inserted into the left radial artery. The patient was then positioned in the left lateral decubitus position for tracheal excision and reconstruction via a right uniport NiVATS.

During tracheal mobilisation and dissection and before the trachea was transected, high-flow oxygen (50–60 L/min) was delivered using an Airvo™ 2 (Fisher & Paykel Healthcare Ltd., Auckland, New Zealand) via a tracheostomy direct connection (Optiflow +, Fisher & Paykel Healthcare Ltd.) through the i-gel 15-mm connector. Despite the use of high-flow oxygen and spontaneous breathing, maintaining the patient's oxygen saturation above 88% was challenging. We then assisted the patient's breathing by providing manual intermittent positive pressure ventilation via the GA machine in spontaneous mode, with oxygen at 15 L/min, which increased her oxygen saturation levels to above 92%.

To maintain acceptable oxygenation and prevent tumour movement during bagging while performing tracheal transection and tumour removal, we employed cross-field ventilation to the distal tracheal stump by requesting the surgeon to intubate the left main bronchus with a size 6 flexo-metallic reinforced endotracheal tube (Figs. 1c and 3c). Tracheal reconstruction began once frozen section analysis confirmed no malignancy on either side of the tumour margins. We intermittently removed the endotracheal tube and selectively ventilated the appropriate bronchus to provide the surgeon access to specific areas of the trachea during reconstruction. We alternated between manual jet ventilation using a Cook airway exchange catheter and cross-field ventilation during tracheal anastomosis, as the patient desaturated easily and oxygenation was difficult to maintain during manual jet ventilation. Small boluses of intravenous atracurium (5–10 mg) were administered to facilitate ventilation during anastomosis. The patient's haemodynamic profile remained stable, with end-tidal carbon dioxide levels ranging from 60–80 mmHg and no significant increase in airway pressure throughout the surgery. After completing the tracheal anastomosis, the patient was able to breathe spontaneously and was able to maintain oxygen saturation of 98–99% *via* the i-gel.

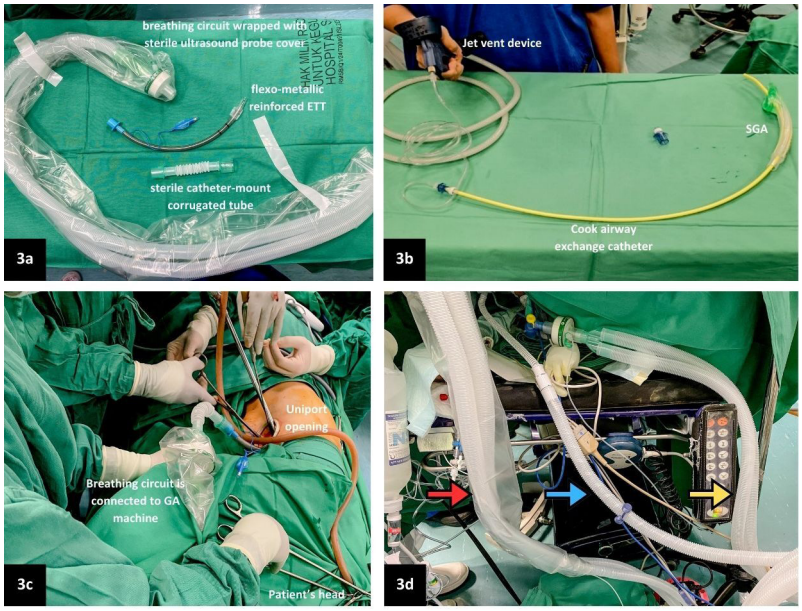

Figure 3 *(a)* The equipment for cross-field ventilation prepared by the surgical scrub team, including a flexo-metallic reinforced endotracheal tube (ETT), sterile catheter-mount corrugated tube, and a breathing circuit wrapped with a sterile ultrasound probe cover. *(b)* Preparation for manual jet ventilation using a supraglottic airway (SGA) device. The Cook airway exchange catheter is inserted through the SGA glottic opening and attached to the jet vent device. *(c)* A flexo-metallic reinforced ETT is inserted into the distal tracheal stump by the surgeon, through a uniport opening over the right chest. The sterile breathing circuit is connected to the general anaesthesia machine. *(d)* Different breathing circuit at the patient's head. Red arrow: cross-field ventilation; blue arrow: high-flow oxygen device; yellow arrow: breathing circuit to the general anaesthesia machine

The patient was extubated to a facemask with 5 L/min oxygen and transferred to the post-anaesthesia care unit for close monitoring. Postoperative chest X-ray revealed a left-side pneumothorax (Fig. 1d). No intervention was necessary as the patient remained asymptomatic, and the right chest tube was functioning well. Bronchoscopy performed on postoperative day 1 revealed a small tracheal cartilage fragment lodged in the left main bronchus. The fragment was successfully removed endoscopically. The final histological diagnosis was reported as benign hamartomatous polyp.

The patient's pain was manageable with oral analgesics during her hospital stay. She did not experience any other complications, such as dysphagia or voice changes. A repeated bronchoscopy prior to discharge on postoperative day 8

and at 1-month post-surgery showed an intact anastomosis. She stated that her functional status improved after the surgery.

Discussion

A common option for airway management during tracheal resection and reconstruction surgery typically involves endotracheal intubation, followed by cross-field ventilation during anastomosis. However, with appropriately selected patients, experienced anaesthetists, and skilled surgeons, NiVATS may offer additional benefits for tracheal resection.[1] The exclusion criteria for NiVATS patients are the following: obesity (body mass index ≥ 30 kg/m^2), anticipated difficult airway, American Society of Anesthesiologists Class 3 or higher, haemodynamic instability, elevated intracranial and pulmonary pressure, excessive airway secretions, persistent cough, risk of gastric regurgitation, and surgeries expected to last more than 5 hours. [1,3]

Over the past 3 years, our centre has successfully performed 3 NiVATS procedures out of 14 tracheal resections, with no conversions to intubation.[4,5] Based on the criteria for NiVATS, our patient was deemed a suitable candidate. More importantly, her tracheal lesion was located 1 cm from the carina and caused 90% tracheal obstruction, making NiVATS with SGA device —a tubeless technique—the best option of intraoperative airway management to facilitate the surgical procedures. The choice of airway management device is the responsibility of the attending anaesthetist, with common options including SGA device, facemask, Venturi mask, high-flow nasal cannulas, with nasal cannulas being the least favoured option.[6]

In NiVATS, desaturation is not uncommon. It can occur initially when artificial pneumothorax is introduced and later during tracheal transection and anastomosis. Oxygenation generally improves within 5 to 10 minutes after artificial pneumothorax because pulmonary mechanics are preserved without muscle relaxants, and effective contraction of the dependent hemidiaphragm during spontaneous one-lung ventilation (OLV) ensures a favourable match between ventilation and perfusion.[2]

High-flow oxygen and manual jet ventilation via an SGA device are usually appropriate remedial manoeuvres if the patient desaturates during tracheal dissection.[6] Most of the time, oxygen is effectively delivered to the distal resected trachea due to the high flow applied across it via diffusion. Notably, this case report is the first to highlight the use of high-flow oxygen via an SGA device,

delivering up to 60 L/min of oxygen during NiVATS. The use of high-flow oxygen was part of our initial planning for this patient.

Our patient did not experience desaturation when artificial pneumothorax was initiated. She did subsequently desaturate during tracheal transection despite the aforementioned manoeuvres, with oxygenation remaining below 88% for long periods. Therefore, as the last resort, we had to employed intermittent selective cross-field ventilation during tumour manipulation and removal. She was able to maintain acceptable oxygen saturation levels (88–95%) beyond tumour removal stage until completion of tracheal anastomosis; her saturation exceeded 95% during the closure phase.

Contralateral pneumothorax is a rare but life-threatening complication of OLV. It can occur due to surgical or anaesthetic procedures that breach the pleura, with its incidence being even lower in spontaneously ventilating patients.[7,8] One possible explanation for the difficulty in maintaining optimal oxygenation during spontaneous OLV intraoperatively for this patient was pneumothorax of the contralateral lung. This can occur when the surgeon dissects the mediastinal pleura and accidently incises the contralateral lung pleura. The predicted ventilation/perfusion match was not achieved due to the presence of pneumothorax in the dependent lung. Apart from the clinical signs that arise from impaired respiratory mechanics (increased peak airway pressure, low tidal volume, hypoxaemia, and hypotension), it is possible for the surgeon to diagnose contralateral pneumothorax macroscopically by assessing mediastinal herniation into the non-dependent hemithorax.[9] However, as the contralateral pneumothorax was small in this patient, the sign was not noticeable. Furthermore, compared to patients with extensive thoracotomy, this sign can be harder to detect in limited views of VATS.[7]

Conclusion

Pneumothorax is always a diagnosis of exclusion during general anaesthesia due to its variable and non-specific clinical presentations. It should remain as one of the differential diagnoses for hypoxaemia in high-risk surgeries such as NiVATS. Contingency airway plans are vital in managing patients undergoing NiVATS for tracheal resection and reconstructions to prevent airway mishaps. Nevertheless, NiVATS is a feasible approach for tracheal surgery in suitable patients.

Declarations

Informed consent for publication

The patient provided informed written consent for the publication of the clinical data contained in this case report.

Competing interests

The authors declare that they have no competing interests.

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None to declare.

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Tailored airway management for simultaneous thyroidectomy and tracheal stenosis tumour biopsy: navigating dual pathologies

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Abstract

Tracheal stenosis secondary to tumour presents potential airway complications such as bleeding, airway oedema, laryngospasm and bronchospasm secondary to airway irritation, and difficulty advancing the endotracheal tube through the slit-like diameter of the trachea lumen. We present a case with double pathology of goitre and intraluminal tracheal tumour for thyroidectomy and tumour biopsy. A multidisciplinary discussion was held preoperatively between the otorhinolaryngology surgeons, radiologist, and anaesthesiologists to define resectability and perioperative management. The awake fibreoptic intubation oral approach using a microlaryngeal tube size 5 with target-controlled infusion of remifentanil sedation was successful. The airway was anaesthetised with a sphenopalatine ganglion block, palatopharyngeal arch nerve block, nebulisation lignocaine, and spray-as-you-go lignocaine to obtund the pharyngeal and laryngeal reflexes. Post thyroidectomy, direct rigid laryngoscopy was performed for tumour biopsy. The patient was later admitted to the intensive care unit for postoperative ventilation and monitoring. We learned that there is no single universal airway technique for airway management as it should be tailored based on the individual patient's airway pathology and comorbidities after careful perioperative discussion and airway planning.

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Keywords: airway management, awake fibreoptic intubation, remifentanil, tracheal stenosis, tracheal tumour

Introduction

Airway management in a large multinodular goitre (MNG) frequently involves a video laryngoscope and awake tracheal intubation (ATI) due to a potentially difficult airway. In addition, intratracheal tumours may worsen tracheal stenosis, with the possibility of airway complications such as bleeding, oedema, and laryngospasm. Careful management of double airway pathologies requires careful perioperative planning, as any complication may lead to a "cannot intubate, cannot oxygenate" scenario.

Case presentation

We present a 53-year-old woman with underlying controlled bronchial asthma on 2 puffs twice a day of the metered dose inhaler steroid and no prior history of intensive care unit (ICU) admission or intubation.

Two years prior to presentation, she had been diagnosed with benign follicular lesion MNG confirmed by fine-needle aspiration cytology. An ultrasound of the neck had revealed MNG, with the right thyroid measuring 1.4 cm x 2.6 cm x 3.9 cm and the left thyroid measuring 1.6 cm x 2.3 cm x 3.6 cm. A contrast-enhanced computed tomography (CT) of the neck showed the right thyroid measuring 3.1 x 2.3 cm x 5.2 cm, while the left thyroid measured 2.7 cm x 2.4 cm x 5.8 cm. There was no retrosternal extension. The CT scan also showed a subglottic mass suggestive of a soft tissue lesion located on the right side, posteriorly, crossing the midline and commencement of the trachea measuring 1.5 cm x 1.3 cm x 1.4 cm. This mass caused a tracheal stenosis measuring 5 mm in diameter. The patient defaulted follow-up until after a year, when she developed chronic cough and throat discomfort.

Upon presentation at our centre, the patient had no difficulty breathing, dysphagia, or hoarseness of voice. She was euthyroid on tablet carbimazole 5 mg daily. A repeated CT scan of the neck showed an intratracheal mass measuring 5.1 mm with a tracheal lumen diameter of 1.1 cm x 0.7 cm. Direct flexible laryngoscopy confirmed normal epiglottis, vallecula, arytenoid, aryepiglottic fold, and fossa. The vocal cord was mobile and symmetrical, and there was a subglottic mass over the posterior part of the trachea, which looked pinkish and was not fungating.

Given the patient's multiple comorbidities and complex airway problems, a multidisciplinary discussion was held to make choices regarding the lesion's resectability as well as surgical and anaesthetic perioperative management, including airway management. After discussion, the plan was to proceed with total thyroidectomy, followed by tracheal tumour biopsy.

Preoperatively, nebulisation with 4 ml lignocaine 2% was administered over 5 minutes. This was followed by a pterygopalatine ganglion block using a cotton bud dipped with 5 ml lignocaine 2% and phenylephrine 50 mcg inserted into the right nostril to the posterior nasopharyngeal wall. Xylocaine 10%, 0.1 ml ~ 20 mg, was sprayed twice over the bilateral posterior pharyngeal wall at the base of the palatoglossal arch to block the glossopharyngeal nerve. The patient also gargled 8 ml lignocaine 1% and swallowed it followed by administration of intravenous (IV) glycopyrrolate 200 mcg as an anti-sialagogue.

Sedation technique

Sedation was commenced with IV 1 mg midazolam followed by target-controlled infusion (TCI) of remifentanil using the Minto model at 3 to 4 ng/ml. The anaesthesiologist stood in front of the patient since the patient was more comfortable in the sitting position. An Ovassapian airway was inserted, and the patient was instructed to open her mouth to facilitate fibreoptic insertion. We used a paediatric, single-use, 3.5-mm Storz Fibreoptic Intubation Video Endoscope (KARL STORZ, Tuttlingen, Germany) to facilitate the insertion of a 5.0-mm microlaryngoscopy tube (MLT). We increased the TCI remifentanil slowly until 8 ng/ml for a brief period during the insertion of the endotracheal tube (ETT) through the trachea. Upon successful intubation, total intravenous anaesthesia-TCI was maintained with TCI propofol 3 µg/ml and TCI remifentanil 3 ng/ml was given under bispectral index (BIS) monitoring to keep BIS between 40 and 60.

After the thyroidectomy, the otorhinolaryngology team decided to perform direct laryngoscopy and telescoping. This was based on the discussion of intraoperative airway planning between the otorhinolaryngology surgeons and anaesthesiologists supported by the initial awake fibreoptic intubation (AFOI) video findings in Figure 1a. The tumour was approximately 0.5 cm from the vocal cord and 1.5 cm posterior to the lateral location in Figure 1b. Following the tissue biopsy, as shown in Figure 2, the otorhinolaryngology team replaced the MLT with a 7.0-mm ETT under direct rigid scope. The fibreoptic procedure showed that there was no airway collapse during respiration, and tracheomalacia was ruled out by the surgeon after thyroidectomy. The patient was then admitted to the ICU for postoperative monitoring and ventilation and was transferred to the general ward the next day.

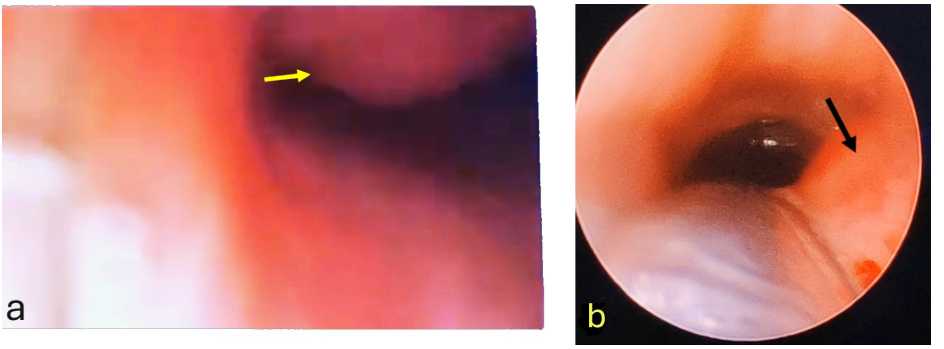

Fig 1. (a) Tumour in the posterior wall during AFOI as shown by yellow arrow (oral approach and operator at patient's front). *(b)* Rigid laryngoscopy view with MLT in situ. The black arrow shows the tumour just beside the MLT.

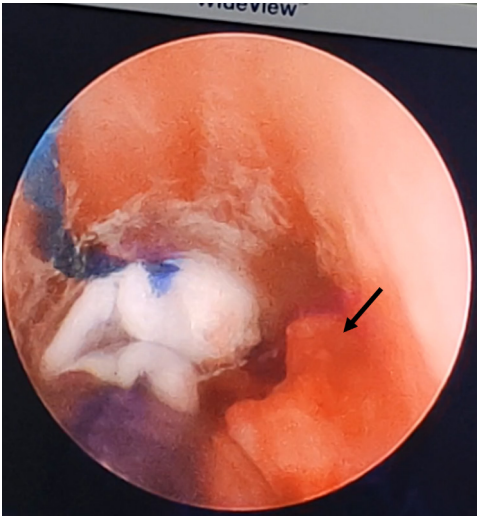

Fig 2. Arrow shows intratracheal tumour after biopsy.

Discussion

MNG may cause external compression of the trachea, while prolonged MNG may also potentially cause tracheomalacia with an incidence of 1.4%.[1] In comparison, intratracheal tumours present another ventilation concern due to critical airway stenosis with intratracheal airway obstruction.[2-4] Among the airway management considerations were the high possibility of bleeding upon touching the tumour,[5] airway oedema[6] upon multiple intubation attempts with loss of ability to ventilate, and airway irritation causing laryngospasm or bronchospasm.[2,5,6]

In this case, the patient presented with both MNG and intratracheal tumour, which required 2 procedures by the endocrine and otorhinolaryngology surgeons. The endocrine surgeon's preference was intraoperative nerve monitoring (IONM) to help prevent recurrent nerve injury, while the otorhinolaryngology surgeons required space for the intratracheal procedures. As anaesthetists and airway experts, facilitating both surgical teams' requirements was among our primary goals. However, airway management must balance the necessity with potential airway manoeuvres and complications, as described in Table 1.

Table 1. Options for airway management in this case

Options	Airway technique	Advantages	Disadvantages
A	AFOI using IONM with the smallest size ID of 6.0 mm (ED of 8.5 mm).	AFOI has a proven safety and success rate.5,7 IONM helps monitor nerve conduction to prevent recurrent laryngeal nerve injury during thyroidectomy.8	AFOI requires an adequate level of sedation and topical anaesthesia.2 Tube size larger than the tracheal slit has the probability of difficult ETT insertion. Need to change ETT during tracheal tumour biopsy.
B	AFOI using 3.5-mm single-use Storz to insert MLT size ID 5 mm (ED 6.5 mm), smallest size ID 4.0 (ED 5.6 mm). Followed by rigid bronchoscopy by the ENT team.	AFOI has a proven safety and successful rate.5,7 MLT may protect the airway during tumour manipulation without obstructing the surgical field view.	AFOI procedure requires an adequate level of sedation and topical anaesthesia.2 A small size of fibreoptic to fit the small lumen MLT should be available. MLT might impair lesion visibility.

Options	Airway technique	Advantages	Disadvantages
C	Aintrée intubation catheter and jet ventilation	Allows jet ventilation and the insertion of a fibreoptic tube if needed.	Inadequate gas exchange/ventilation via the narrow lumen and risk of pneumothorax.2
D	Awake tracheostomy	Opportunity to electively secure the airway before surgical manipulation to prevent airway crisis.	Risk of tracheostomy-related complications.9 Difficulty of performing tracheostomy before thyroidectomy. Tracheostomy might not be needed postoperatively.

AFOI: awake oral fibreoptic intubation; ED: external diameter; ENT: ear, nose, throat ID: internal diameter IONM: intraoperative nerve monitoring; MLT: microlaryngoscopy tube

Several approaches to securing airway in tracheal procedure have been described in the literature.[5,7,10,11] For example, Koul *et al.*[6] reported airway manoeuvres using rigid bronchoscopy alone. However, the intratracheal mass may get detached and dislodged distally, leading to distal airway obstruction. The bleeding during removal may also lead to respiratory problems. Satoh *et al.*[3] reported a successful case using high-frequency jet ventilation, but there was a risk of barotrauma and potential airway obstruction by the mass. Therefore, we decided to use Option B as described in Table 1, which the surgical team agreed to as the monitoring of recurrent laryngeal nerve can be done surgically.[9] This is because there is a significant chance that the IONM tube size will not fit through the trachea. MLT also offers better tumour visibility due to its small external diameter.

After thyroidectomy, the decision to proceed with direct rigid laryngoscopy and telescoping was made after considering the nature of the tumour and the ability to proceed with the MLT tube in situ. If there was a difficulty, the plan was to proceed with jet ventilation with tracheostomy being the last resort.[2,10] The main learning point from this case was the opportunity to familiarise ourselves with multiple airway devices and the option to secure a challenging airway. For instance, we needed to be well-versed with the external diameter of each ETT and the diameter of the flexible bronchoscope to pass through the small tracheal lumen. Additionally, the key to successful ATI is the appropriate method of anaesthetising the airway. This requires a basic knowledge of upper airway anatomy.[7,11]

For sedation during AFOI, remifentanil offers intense analgesia and sympatholytic effects, which is rapidly titratable.[10,12] We used TCI remifentanil, increasing the dose up to 8 ng/ml for a brief duration during the tracheal passage of the ETT and quickly reducing the dose back to 3 ng/ml once the ETT was in situ. This was also described in other case reports with clinical endpoints of patient comfort, relief of anxiety, and pain for this procedure.[13] However, it is essential to recognise the tendency of remifentanil to cause opiate-induced hyperalgesia,[14,15] where the recommended dosage for remifentanil is 1–3 ng/ml.[12] Upon assessment, our patient was comfortable throughout the procedure with a tolerable pain score postoperatively.

Conclusion

Airway management in difficult and rare situations requires multidisciplinary care and good communication throughout the perioperative period. Most of the time, ATI can be done successfully with adequate airway anaesthesia and procedural sedation, provided there is appropriate airway planning in case of a failed airway. Nonetheless, balanced anaesthesia with excellent postoperative analgesia and admission to the postanaesthetic intensive care unit should be routine.

Declarations

Informed consent

The patient consented to the publication of the clinical data and images contained in this case report.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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