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Editorial

National postgraduate medical curriculum: enhancing anaesthesiology training in Malaysia

Azrina **Md Ralib**[1], Noorjahan Haneem **Md Hashim**[2], Ina Ismiarti **Shariffuddin**[2]

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Postgraduate medical education in Malaysia started in 1973 with the launch of two clinical postgraduate programmes, Master of Psychological Medicine and Master of Pathology, by Universiti Malaya. Subsequently, the Government of Malaysia decided the responsibility for postgraduate medical education should rest with the universities, with the involvement of the Academy of Medicine of Malaysia (AMM) and the Ministry of Health (MOH). To date, Malaysian universities offer 23 postgraduate clinical programmes, including Master of Anaesthesiology. These programmes are conducted at individual universities, but in the spirit of uniformity, they are run in collaboration with all universities offering similar programmes as well as the AMM, and the MOH.

There are two pathways for postgraduate anaesthesiology training in Malaysia: the university pathway and the parallel pathway. The university pathway started in 1988; to date, seven universities offer the training programme.[1] The Anaesthesiology Specialty Committee (*Jawatankuasa Kepakaran Anestesiologi)* coordinates training for the university pathway and is responsible for the entrance exam, trainee selection, and conjoint Part I and Part II examinations. The parallel pathway programme, the Fellowship of College of Anaesthetists of Ireland, was recognised by the MOH in 2014. The training programme and Certificate of Completion of Training is organised and managed by the MOH and the College of Anaesthesiologists Academy of Medicine Malaysia.[2]

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The Ministry of Higher Education (MOHE) developed the National Postgraduate Medical Curriculum (NPMC) in 2014 to deliver a unified and structured curriculum for training medical specialists throughout Malaysia. It provides a standardised framework to ensure postgraduate training is of the highest standard, thus safeguarding patient safety and quality of care. The first cohort of NPMC documents for 12 specialties was launched in August 2021. The NPMC for Anaesthesiology Training Curriculum was launched recently in the second cohort October 2023.[3] The launch marks the continuous efforts of the MOHE, MOH, and the Anaesthesiology Specialty Committee to improve the standard of training and subsequently patients care in Anaesthesia and Critical Care.

The NPMC Anaesthesiology bridges and harmonises the university and parallel pathways. The launch of NPMC Anaesthesiology affects Anaesthesiology training in Malaysia in the following ways:

1. Ensures standardisation across different programmes: NPMC Anaesthesiology provides a common structure and process guide for programme owners to deliver standardised teaching, learning, and assessment to achieve common outcomes for anaesthesiology training in Malaysia. This is important to all stakeholders in ensuring that training standards and outcomes are similar across different platforms.
2. Assists in the accreditation processes: NPMC Anaesthesiology complies with the *Malaysian Standards for Medical Specialist Training* by the Malaysian Medical Council[4] and the *Code of Practice for Programme Accreditation* by the Malaysian Qualification Agency (MQA), providing a basic framework for higher education providers and institutions in preparing for programme accreditation.
3. Provides clear expectations for trainee selection: In addition to the current entry requirements, NPMC Anaesthesiology includes eight Entry Essential Learning Activities (ELAs) indicating the required knowledge, skills, and attitudes to demonstrate before programme entry. This allows trainers and trainees to prepare adequately before entering the programme.
4. Provides clear expectations of standards: NPMC Anaesthesiology provides a comprehensive, structured curriculum and expected level of attainment for knowledge, skills, and professional behaviours at each stage of training.[5] This provides an important guide for trainers in teaching, facilitating learning, and assessing trainees.

5. Emphasises competency-based training: The syllabus and learning opportunities are arranged for increasing competence achievement at each specific module and stage of training.[6] Furthermore, incorporating structured formative assessments supports the development of specific skills and abilities necessary for the anaesthesiologist.
6. Integrates technology: With rapid technological advances, its contribution to medical education should be emphasised. Simulation-assisted learning is instrumental in providing a safe and controlled environment for learning crises, managing rare conditions, and practising procedures.[6] It also allows for effective feedback and repetitive practice, making individualised learning possible.
7. Enhances collaborative activities between different institutions: NPMC Anaesthesiology provides a shared framework across different programmes and institutions, creating opportunities for a shared training programme, for example, a common platform for e-learning. E-learning is beneficial as it offers flexibility and accessibility to a larger target audience. Sharing educational resources between higher education providers can further enhance the teaching and learning processes by reducing the trainers' academic burden and providing trainees access to experts and collaborators across institutions.
8. Standardises exit criteria across different programmes: NPMC Anaesthesiology provides standardised exit criteria with nine Exit ELAs outlined, which demonstrate the knowledge, skills and attitude required and behavioural markers expected of a trainee about to exit the programme. This ensures that graduates from all programmes achieve equal standards.

Postgraduate medical education in Malaysia has evolved over 40 years since its inception. It has produced thousands of medical specialists fulfilling the needs of the country's healthcare system. NPMC provides an excellent platform to ensure the standards for producing competent specialists for the country. A periodic curriculum review is essential to evaluate the need for change as medicine evolves. Hesitancy for a change will impede progress and the delivery of effective training, eventually compromising our health care system's future.

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The effect of moderate versus deep neuromuscular blockade on the surgical rating scale in laparoscopic sleeve gastrectomy in a Malaysian tertiary university hospital: a randomised clinical trial

Hajar Rubihah **Dzaraly**[1], Syarifah Noor Nazihah **Sayed Masri**[2], Khairulamir **Zainuddin**[3], Nik Ritza Kosai **Nik Mahmood**[4], Maryam **Budiman**[2], Azarinah **Izaham**[2]

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Abstract

Background: The depth of neuromuscular blockade (NMB) is important to provide optimal space during laparoscopic surgery, especially in the obese population. This study compared the effects of moderate versus deep neuromuscular blockade on the surgical rating scale in laparoscopic sleeve gastrectomy.

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Methods: This single-blind, randomised controlled trial involved 24 patients with a body mass index > 30 kg/m^2 who underwent laparoscopic sleeve gastrectomy. They were randomised into two groups: moderate NMB with a target train-of-four (TOF) of 1-2 (Group M) and deep NMB with a post-tetanic count (PTC) of 1-2 (Group D). The quality of the surgical field was scored by a surgeon using the 5-point Surgical Rating Scale (SRS) from 1 (extremely poor condition) to 5 (optimal condition). The haemodynamic changes, end-tidal CO_2, duration of surgery, and intraabdominal pressure were also recorded. At the end of surgery, patients were given intravenous sugammadex at 2 mg/kg if the TOF count was 12, or 4 mg/kg if the PTC was 1-2. Patients were extubated when the TOF ratio (T4/T1) was greater than 0.9.

Results: The mean SRS was significantly higher in Group D (4.83 ± 0.39) compared with Group M (4.08 ± 0.79), *p*-value = 0.004. All patients in Group D had favourable surgical conditions, in which 16.7% of patients achieved SRS of 4 and 83.3% had SRS of 5. In Group M, 8.3% of patients had an unfavourable surgical field.

Conclusion: A deep NMB provided a favourable surgical condition compared with a moderate NMB in the laparoscopic sleeve gastrectomy.

Keywords: gastrectomy, laparoscopic procedure, neuromuscular blockage, satisfaction

Introduction

Obesity is a serious health problem that occurs more commonly nowadays and is usually associated with a series of comorbidities, such as diabetes mellitus and cardiovascular diseases.[1] According to a nationwide survey conducted in Malaysia in 2019, there has been an upward trajectory in the prevalence of obesity. The rates have escalated from 15.1% in 2011 to 17.7% in 2015, ultimately reaching 19.9% in 2019.[2,3] Obesity can be treated medically or surgically. Medically, obesity is treated by diet modifications, regular physical activities, and weight-loss medications.[4] Surgically, a few procedures can be recommended for appropriate patients. These procedures are called bariatric surgeries and can be performed either as an open procedure or laparoscopically. Laparoscopic techniques have become more popular recently because of their multiple benefits, which include a reduction in postoperative pain, smaller surgical scars, shorter hospital stays, and less postoperative pulmonary impairment.[5,6]

The challenges of laparoscopic surgery are numerous, which may include a poor surgical field with inadequate space and volume, especially in an obese population. Studies showed that the routine use of neuromuscular blocking agents up to the level of deep blockade might help overcome these problems.[7] Deep neuromuscular blockade (NMB) was associated with a better surgical condition than moderate muscle relaxation, especially during low-pressure laparoscopic surgery. Laparoscopic surgery performed with an intra-abdominal pressure of 12 to 15 mmHg is associated with fewer deleterious effects on pulmonary function and haemodynamics. However, deep blockade may result in poor recovery of muscle function at the end of surgery. It is associated with the risk of postoperative complications such as prolonged emerging time from anaesthesia, significant impairment of pharyngeal muscle function post-extubation, obtundation of hypoxic ventilatory drive, and reduced respiratory function, particularly in obese patients.[8]

Intraoperatively, the degree of blockade at the neuromuscular junction is monitored with a neuromuscular monitoring device, either with a train-of-four (TOF) count for a moderate block or a post-tetanic count (PTC) for a deep block.[9] In certain circumstances, a deep block (PTC 1–2) is required to achieve good surgical conditions.[10] The routine use of neostigmine as a reversal agent does not guarantee a complete return of neuromuscular function. The introduction of sugammadex, a gamma-cyclodextrin molecule with high affinity for aminosteroidal neuromuscular blocking agents such as rocuronium, can rapidly reverse deep neuromuscular blockade.[11]

This study was conducted to assess the effect of moderate versus deep NMB on laparoscopic sleeve gastrectomy in a single tertiary university hospital in Malaysia. In this study, laparoscopic sleeve gastrectomy was chosen since it is the most common surgery performed in our centre when compared to other types of bariatric procedures such as gastric bypass or gastric banding. It is also the most common type of bariatric surgery performed worldwide.[12] Selecting a single procedure can probably minimise the bias in this study. It was hypothesised that there was no difference in the surgeon's satisfaction and duration of surgery between moderate and deep neuromuscular blockade.

Methods

This was a single-blinded, randomised controlled trial involving 24 patients who underwent laparoscopic sleeve gastrectomy under general anaesthesia from March to October 2016 at a tertiary university hospital. The study was conducted in accordance with the Declaration of Helsinki and approved by the Medical Research and Ethics Committee of Universiti Kebangsaan Malaysia Medical Centre (FF-2015-361). Patients scheduled for the surgery were recruited, and written informed consent was obtained.

Eligible patients were more than 18 years old and obese with a body mass index (BMI) of more than 30 kg/m^2. Patients with coexisting neuromuscular diseases, known hypersensitivity to drugs that were used in this study, liver impairment, significant renal impairment (creatinine clearance < 30 ml/min using Cockcroft-Gault Formula), and previous abdominal surgery or revision of laparoscopic bariatric surgery were excluded from this study. With respect to the degree of NMB, the patients were assigned randomly into two groups: a moderate block with a TOF count of 1–2 (Group M) and a deep block with a PTC of 1–2 (Group D) using a computer-generated randomization code. The code was given to the anaesthesiologists in charge of the patients prior to the induction of anaesthesia.

Standard anaesthetic monitoring was applied throughout the procedure, consisting of non-invasive blood pressure, an electrocardiograph, pulse oximetry, end-tidal carbon dioxide ($etCO_2$), nasopharyngeal temperature monitoring, and multigas analysers. Additionally, NMB was monitored every 10 minutes with a Neuromuscular Transmission (NMT) Sensor Cable (GE Datex-Ohmeda, Helsinki, Finland). Neuromuscular monitoring was done over the ulnar nerve of the left or right wrist. The mechanosensor was attached to the ipsilateral thumb and second finger with tape. After induction of anaesthesia but prior to administration of muscle relaxants, the device was calibrated to get the supramaximal stimulus. The device started the measurement by setting the stimulus current automatically and by performing a reference measurement.

Prior to induction of anaesthesia, all patients were positioned in the ramped position to achieve optimal intubation conditions. They were given intravenous fentanyl (2 mcg/kg lean body weight, LBW) and propofol (2 mg/kg LBW). Depending on the preoperative airway assessment, muscle paralysis was induced either with intravenous suxamethonium 1.5 mg/kg total body weight (TBW) or rocuronium 0.6 mg/kg ideal body weight (IBW), according to anaesthetist preference. All patients were intubated using a C-MAC® video laryngoscope (Karl Storz GmbH & Co. KG, Tuttlingen Germany). None of the patients required awake fibreoptic intubation. For those patients who received suxamethonium for intubation, a bolus dose of rocuronium (0.6 mg/kg IBW) was given subsequently. Anaesthesia was maintained with a mixture of air, oxygen, and desflurane with a minimum alveolar concentration of approximately 1.0–1.2. All patients received 10 ml of 0.2% ropivacaine as local anaesthesia, intravenous parecoxib 40 mg, and intravenous paracetamol 1g as a standard analgesia.

Patients in Group M were given intravenous rocuronium 10 mg intermittently to achieve a TOF count of 1–2 (moderate block), while in Group D patients received regular boluses of intravenous rocuronium 10 mg every 15–20 minutes with the aim of maintaining PTC 1–2 (deep block).

Each laparoscopic operation in this study was conducted by a surgeon who possessed considerable experience but was unaware of the group allocation. Measurements of blood pressure, heart rate, pulse oximetry, $etCO_2$, and neuromuscular monitoring were recorded every 30 minutes. In addition, the duration of surgery, gas flow, and intra-abdominal pressure were also documented every 30 minutes. The intraabdominal pressure was set at 12 mmHg (low pressure), but in the event of inadequate surgical visibility, the pressure and gas flow were increased accordingly and recorded.

At the end of surgery, all patients were given a reversal agent: intravenous sugammadex, 2 mg/kg corrected body weight (CBW) if TOF count 1–2, or 4 mg/kg CBW if PTC 1–2. Patients were extubated when the TOF ratio (T_4/T_1) was greater than 0.9. The definitions of IBW, TBW, LBW, and CBW are listed in Appendix 1.

An evaluation form was handed to the surgeon after the completion of surgery to evaluate the level of satisfaction and the ease of surgery in both groups of patients. The 5-point Surgical Rating Scale (SRS) (Appendix 2) was used based on a previous study done by Martini *et al.* SRS of 4 or 5 was considered a favourable condition for laparoscopic surgery.

Statistical analysis

The sample size was calculated with reference to Martini *et al.*, who concluded that the rating during a moderate block is 30% in the SRS of 4 or 5, and the rating during a deep block is 90% in the SRS of 4 or 5.[13] The α-value was set at 5% and the power of study at 80%. A sample size of 24 was calculated with a dropout rate of 10%.

Statistical analysis was performed using the IBM SPSS statistical software package (version 23.0). Sociodemographic data were analysed descriptively and presented as frequencies and percentages. All values were shown as mean ± standard deviation (SD) or median (range), and the number of patients (%) was used for all categorical data. Comparisons of variables between groups were performed by independent Student's t-test, a Mann-Whitney-U test, and a chi-square. A p-value of less than 0.05 was considered significant.

Results

A total of 24 patients were recruited for this study. They were allocated to the respective groups, and intervention was carried out according to the protocol. Figure 1 shows the consort flow diagram of the study. Demographic data are shown in Table 1. The weight was significantly higher in the deep group, but BMI was comparable between the two groups.

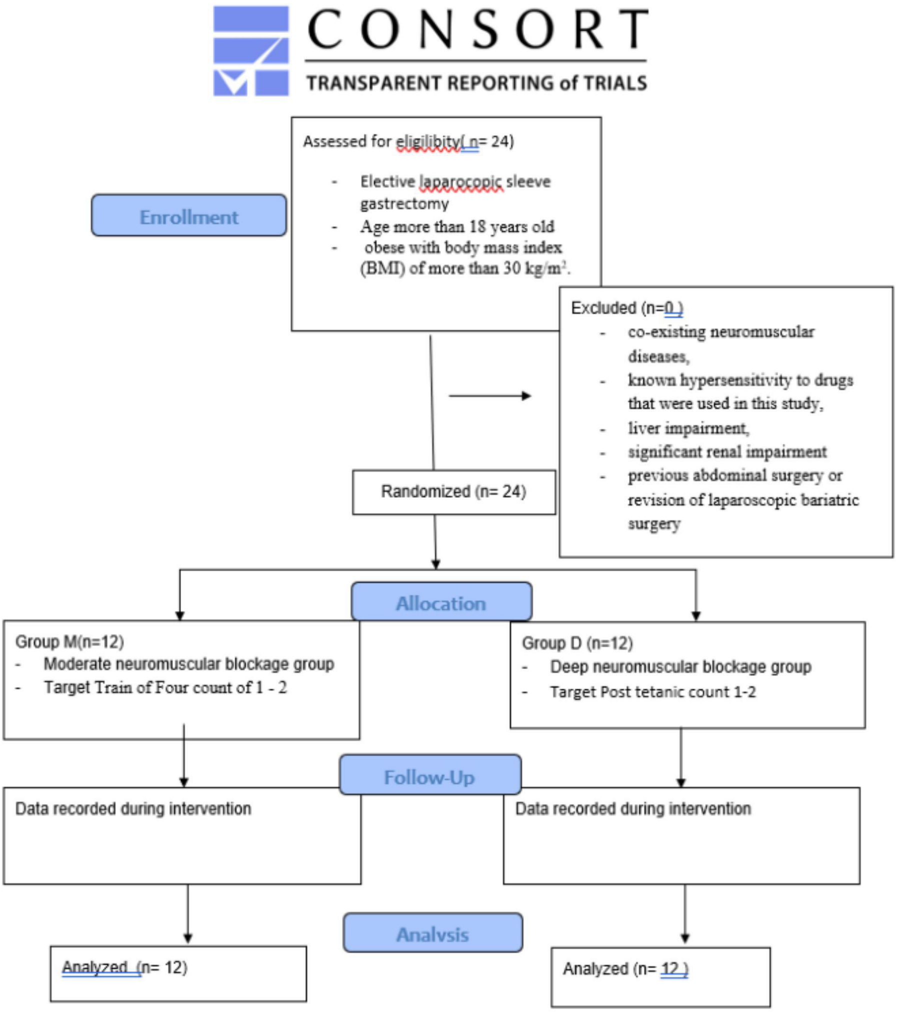

Fig. 1. Consort flow diagram.

Table 1. Demographic data

Variable	Group M (n = 12)	Group D (n = 12)	*p*-value
Age (y)	40.5 (10.9)	40.8 (10.3)	0.945
Gender (male or female)	7:5	5:7	
Height (m)	1.65 (0.09)	1.60 (0.08)	0.164
Weight (kg)	123 (29)	101 (14)	0.027*
Body mass index (kg/m2)	45.1 (10.7)	39.6 (5.3)	0.125
Race			
Malay	9	8	
Chinese	1	0	
Indian	1	2	
Bidayuh	0	1	
Non-Malaysian	1	1	

All values are the mean (SD) or number of patients.
*Indicates statistical significance

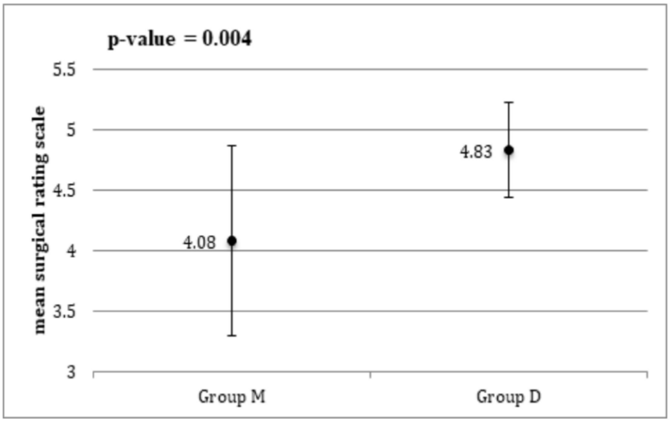

Fig. 2. Mean surgical rating scale obtained during the surgery A circle indicates the mean (SD).

Table 2 shows the hemodynamic parameters and the surgical data. Hemodynamic changes and intra-abdominal pressure measured during the procedure did not differ significantly between both groups. There was also no significant difference in the duration of surgery between both groups. The average duration of surgery was 157.0 minutes in Group M (range 105–210, median 157.5) and 178.8 minutes in Group D (range 135–250, median 167.5), with a p-value > 0.05. The mean dosage of opioids and anaesthetic agents was higher in Group M, as they were correlated to the weight of the patients seen in the demographic data. The mean dosage of sugammadex used was significantly higher in the moderate group. The mean SRS score was significantly higher in Group D (4.83 ± 0.39) compared with the score in Group M (4.08 ± 0.79) with a p-value = 0.004 as shown in Figure 2.

The distributions of all ratings taken during surgery are shown in Figure 3. In Group M, a score of 3 or less was observed in 8.3% of patients, and favourable conditions (SRS 4 and 5) were obtained in 91.7% (good 66.7% and optimal 25%), whereas in Group D all patients achieved good and optimal conditions (good 16.7% and optimal 83.3%). In terms of favourable conditions, more patients in Group D received optimal conditions (SRS 5) as compared with the moderate NMB. Figure 4 shows that 83.3% of patients in Group D and only 25% of patients in Group M obtained SRS 5 with a p-value = 0.004. Meanwhile, approximately 66.7% of patients in Group M and 16.7% in Group D achieved an SRS of 4 with a p-value = 0.013. The phi value for both SRS is more than 0.5, which indicates a strong association between the type of NMB and SRS.

Table 2. Measurements obtained during surgery

Variable	Group M	Group D	p-value
Mean blood pressure (mmHg)	83.0 (7.0)	84.0 (8.0)	0.748
Heart rate (min^{-1})	78.0 (10.0)	76.0 (12.0)	0.662
End-tidal CO_2 (mmHg)	40.0 (2.7)	39.5 (2.2)	0.624
Intraabdominal pressure	12.3 (0.6)	12.3 (0.5)	1.000
Duration of surgery (min)	157.0 (42.0)	178.8 (33.0)	0.171
Fentanyl (mcg)	152 (27)	130 (38)	0.058
Propofol (mg)	174 (34)	149 (35)	0.089
Total dose of rocuronium (mg)	93 (27)	103 (27)	0.374
Sugammadex (mg)	165 (25)	138 (21)	0.009*

All values were calculated as the mean (SD).
* Indicates statistical significance

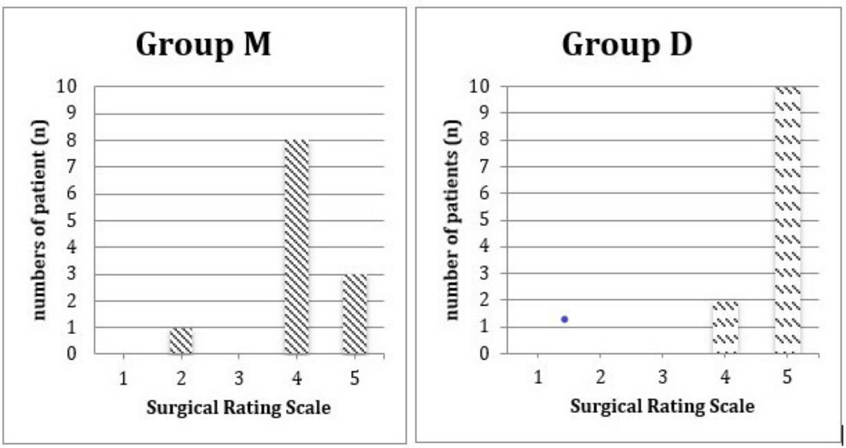

Fig. 3. Distribution of the Surgical Rating Scale (SRS) in moderate and deep blocks.

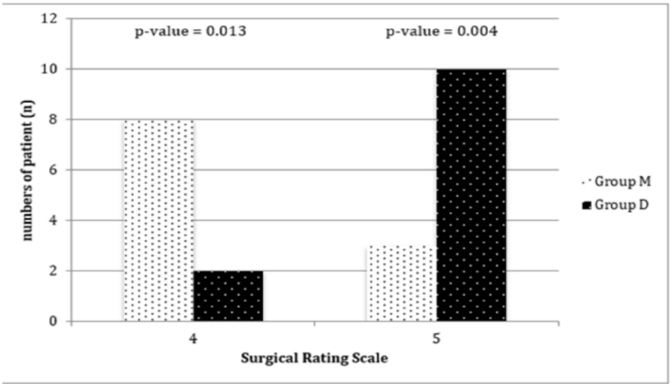

Fig. 4. Distribution of Surgical Rating Scale (SRS) of 4 and 5 in moderate and deep block.

Discussion

In this study, a deep NMB was associated with a higher rating score compared with the moderate NMB in laparoscopic sleeve gastrectomy. We observed that good and optimal conditions can be achieved during moderate NMB, although at a lower frequency (91.7%) than during deep NMB. The present findings align with prior observations in other surgical procedures, which have demonstrated that deep NMB consistently yields significantly higher SRS scores of 4 and 5 in diverse laparoscopic surgeries.[8,13] A meta-analysis also showed that excellent or good surgical conditions can be achieved by deep NMB in laparoscopic surgeries.[14] In our study, 8.3% of patients had unfavourable surgical conditions in the moderate NMB group and none in the deep block group.

The mean intra-abdominal pressure for both groups was 12.3 mmHg. Only one patient in the moderate NMB group required pressure up to 16 mmHg to achieve acceptable surgical space. Other investigators have used an intra-abdominal pressure of 13.2 mmHg for their laparoscopic bariatric surgery. Deep NMB has been shown to allow a lower intraabdominal pressure to be maintained during laparoscopic surgery.[15,16] The study period did not involve any adjustments to the intrabdominal pressure as long as the surgical conditions remained favourable. In a recent meta-analysis of randomised clinical trials, Yiyong *et al.* concluded that low intra-abdominal pressure with deep NBM was not significantly more effective than other intra-abdominal pressure and NMB combinations for optimising surgical space conditions.[17]

Our study found that the hemodynamic parameters were comparable between the two groups. First, we only included patients with no cardiac comorbidities in our population. Laparoscopic procedures can predispose to multiple cardiovascular complications as high intra-abdominal pressure results in increased afterload and a reduction in cardiac output.[18] Low intra-abdominal pressure may be beneficial for high-risk cardiac patients during laparoscopic surgery.[15]

The average duration of surgery in our study was similar between the two groups. This finding aligns with a meta-analysis conducted by Bruintjes *et al.*, which demonstrated a comparable duration of surgery among both groups of patients.[10] However, in a prospective observational study, Garneau *et al.* found that patients in the deep group had a significantly lower duration of surgery.[19]

To evaluate surgical conditions in our study, we used a 5-point SRS that has been validated in several studies.[5,6,13] Other scoring systems that have been used are the numerical rating scale (NRS) or the visual analogue scale (VAS) from 0 to 10. The NRS and VAS only reflect the quantitative aspects of the surgical condition. The scoring system should include the qualitative aspects that are important to surgeons when judging the surgical field. Thus, SRS was chosen due to its qualitative descriptions, which are integrated into the scoring system. To reduce variability, only one surgeon was involved in our study and evaluated the surgical conditions. He was able to discriminate between moderate and deep NMB and considered the changes in SRS to be clinically relevant.

Even though deep NMB has been proven to be beneficial, some anaesthesiologists might be reluctant to induce deep NMB during the entire procedure, especially in the obese population. The use of continuous muscle relaxants may result in hazardous effects such as residual paralysis postoperatively, especially in obese populations.[20] Despite the demonstrated improvement in SRS by surgeons, the clinical implications of deep NMB remain a subject of debate. Most meta-analyses have indicated that there is a comparable difference in surgical time and postoperative pain between the two groups.[9,10] Deep NMB also did not provide a superior surgical space compared to moderate NMB.[17]

The current use of sugammadex makes rapid reversal of deep NMB possible, alleviating concerns about postoperative complications. In our study, all patients were reversed with sugammadex. No respiratory complications were observed in either group in the postoperative anaesthesia care unit or in recovery. A retrospective study was conducted on a cohort of over 3,000 cancer patients who underwent laparoscopic stomach surgery. The findings revealed that patients in the sugammadex group exhibited significantly reduced complications and length of hospital stay as compared to those in the neostigmine group.[21]

The main limitation of our study was its small sample size. We also only assessed the SRS and did not assess other benefits of deep NMB after the procedure. Apart from that, respiratory function, return to routine physical activities, and length of hospital stay were not documented.

Conclusions

A deep NMB provided favourable surgical conditions compared with a moderate NMB in the laparoscopic sleeve gastrectomy. However, there was no difference in terms of haemodynamic parameters, duration of surgery, or intra-abdominal pressure between the groups.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Medical Research and Ethics Committee of Universiti Kebangsaan Malaysia Medical Centre (FF-2015-361). Patients scheduled for the surgery were recruited, and written informed consent was obtained.

Competing interests

Dr Azarinah Izaham serves as Section Editor in Malaysian Journal of Anaesthesiology. She has 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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Appendix 1

Measurement of ideal body weight (IBW), lean body weight (LBW), and corrected body weight (CBW) (18–21)

Ideal body weight calculation

IBW (kg) = height (cm) – x

IBW: ideal body weight

x = 100 for adult males and 105 for adult females.

Lean body weight calculation

LBW (kg) for male = (1.10 x BW) - (0.0128 x BMI x BW)

LBW (kg) for female = (1.07 x BW) - (0.0148 x BMI x BW)

LBW: lean body weight

BW: body weight (total)

BMI: body mass index (kg/m^2)

Corrected body weight calculation

CBW = IBW + (0.4 x excess weight)

CBW (corrected body weight)

IBW: ideal body weight

Appendix 2

Table 1. Surgical Rating Scale (SRS)

SRS	Descriptions
1	Extremely poor condition Unable to work Coughing or inability to obtain a visible field because of inadequate muscle relaxation
2	Poor condition Visible laparoscopic field Surgeon is severely hampered by inadequate muscle relaxation with continuous muscle contractions, movements, or both
3	Acceptable condition Wide visible field Muscle contractions, movements, or both occur regularly
4	Good condition Wide visible field Sporadic muscle contractions or movements, or both
5	Optimal condition Wide visible working field No muscle movement or contraction

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Derivation of a multi-biomarker model for predicting mortality in hospitalised COVID-19 patients

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Abstract

Introduction: This study aimed to derive and assess the performance of a multi-biomarker model from a combination of basic laboratory biomarkers in predicting mortality of hospitalized COVID-19 patients.

Methods: This was a cross-sectional study conducted in a university-affiliated hospital in Malaysia. Data of confirmed COVID-19 patients who were admitted from January 2020 to August 2021 were retrieved including their admission C-reactive protein (CRP), lactate dehydrogenase (LDH), and neutrophil-lymphocyte ratio (NLR). Patients were classified as non-survivors or survivors according to their hospital mortality status. Multi-variable logistic regression analysis was used to derive the multi-biomarker model.

Results: A total of 188 confirmed COVID-19 patients were analysed, of which 46 (23%) died in the hospital. Their mean age was 52 (SD 17) years, 104 (52%) were males, 114 (57%) had severe COVID-19 pneumonia, with mean APACHE II score of 14 (SD 10). On admission, those who died had higher median levels of CRP 96.0 (IQR 39.8–182.0) vs 23.0 (IQR 0–67.0 mg/L, $p < 0.001$), of LDH 973.0 (IQR 706.5–1520.0) vs 515.1 (408.8–738.8 IU/L, $p < 0.001$), and of NLR 10.1 (IQR 5.5–23.6) vs 2.8 (IQR 1.5–5.9, $p < 0.001$).

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The multi-biomarker model had a higher area under the curve (0.866, 95% CI 807-0.925) compared to its constituent individual biomarkers. At its optimal cutoff, this model had 78.9% sensitivity and 76.5% specificity for mortality prediction.

Conclusion: A multi-biomarker model of CRP, LDH, and NLR predicted in-hospital mortality with a very good performance in our hospitalised COVID-19 patients.

Keywords: biomarkers, COVID-19, mortality

Introduction

Being declared a global pandemic in March 2020, coronavirus disease 2019 (COVID-19) has spread worldwide and costs millions of lives. COVID-19 has variable clinical presentation, from asymptomatic or milder symptoms such as cough, fever, sore throat, myalgia, and headache, to more severe manifestations such as confusion, chest pain, hypoxemia, pneumonia, and other complications that require mechanical ventilation and intensive care unit (ICU) admission.[1] Severe COVID-19 has a high mortality risk; therefore, it is important to effectively predict which of these patients are more likely to die in order to provide early and timely intervention.

Many studies have reported that using biomarkers can help to predict the outcome of hospitalised COVID-19 patients. Numerous biomarkers are used for prognostication of COVID-19. Examples of such biomarkers are C-reactive protein (CRP), lactate dehydrogenase (LDH), and neutrophil-to-lymphocyte ratio (NLR). CRP is a non-specific acute phase reactant elevated in infection or inflammation; higher levels indicate more severe infection and have been used as an indicator of COVID-19 disease severity.[2,3] LDH is one of the enzymes of the glycolytic pathway that catalyses the conversion of pyruvate to lactate; elevated LDH levels have been shown to be associated with more severe disease and increased mortality in multiple diseases, including severe COVID-19.[4,5] NLR, obtained by dividing the absolute neutrophil count by the absolute lymphocyte count, has great value in indicating a patient’s overall systemic inflammatory status. Its changes can not only reflect the role of neutrophils in infection, but also reflect the changes of lymphocytes. According to recent studies, NLR has some predictive value in predicting the severity and mortality in patients with COVID-19.[6]

While there are many more biomarkers being evaluated for the prognostication of COVID-19, it is unlikely that a single biomarker approach would be able to reflect the various host responses to the infection. Clinicians and researchers have been making efforts to understand COVID-19, but knowledge of its pathogenesis is still not fully understood. A multi-biomarker approach, one which requires several biomarkers being measured and jointly interpreted, could be a superior alternative to assess prognosis in COVID-19 pneumonia. This is because such an approach would be more likely to reflect the various host responses to the COVID-19 infection.

To date, there have been limited studies available regarding the prognostic use of a multi-biomarker approach in the COVID-19 literature. Studies that measure several biomarkers that are interpreted separately do not constitute a multi-biomarker approach. Derivation of a new multi-biomarker model, perhaps one using inexpensive and routinely available biomarkers, may prove to be useful in predicting the in-hospital mortality of hospitalised COVID-19 patients. The aim of this study was to derive and assess the performance of a multi-biomarker model from the combination of basic laboratory biomarkers, namely CRP, LDH and NLR, in predicting mortality of hospitalized COVID-19 patients.

Methods

Study design and participants

This cross-sectional study was conducted after receiving ethical approval from our institution's Human Research and Ethics Committee (Study protocol code: 21100653). Request of the waiver of written informed consents was granted given that the study involved retrospective chart review of the subjects. The inclusion criteria for the study were adult patients (aged 18 years or above) with confirmed COVID-19 patients who were admitted to our institution between January 2020 to August 2021. Patients with incomplete data of biomarkers of interest were excluded.

Data collection methods

In the included patients, relevant demographic, and clinical data were retrieved from their medical record. The data included their age, gender, ethnicity, comorbidities, stage, and severity of COVID-19 on admission, general and specific treatments received in the first 24 hours of admission, and biochemistry profiles. In addition, CRP, LDH, and NLR, measured in the first 24 hours of hospital admission were recorded retrospectively from the hospital computerised database. Of note, NLR was manually calculated as absolute neutrophil count divided by the absolute leukocyte count.

Statistical analysis

Data analysis in this study was performed using IBM Statistical Package for the Social Sciences (SPSS) software. All categorical variables were presented as frequency and proportion, while all numerical variables were presented as mean and standard deviation, or as median and interquartile range, depending on their normality of distribution.

Comparisons of categorical variables between two groups (survivors and non-survivors) were made using the Chi-square test or the Fisher's exact test, as appropriate. Comparisons of numerical variables between the two groups (survivors and non-survivors), including the biomarkers, were made using the independent T-test or the Mann-Whitney U-test, as appropriate.

To derive the multi-biomarker model, we used binary logistic regression analysis by including all the three biomarkers *i.e.*, CRP, LDH and NLR, as covariates, and in-hospital mortality as the dependent variable, employing the enter method. Using the generated coefficients in the model equation, the probabilities of the event, *i.e.*, in-hospital mortality, were reported. This had a value of 0 to 1. The Hosmer-and-Lemeshow goodness-of-fit test was performed to determine the calibration of the model, in which $p > 0.05$ indicates that the model is well-calibrated.

The prognostic performance of the multi-biomarker model and its constituent individual biomarkers were assessed by the area under the curve (AUC). The AUC ranges from 0.5 (no discrimination) to 1 (perfect discrimination). Clinical validity is assumed at an AUC of more than 0.7. The sensitivity and specificity of the biomarkers at the optical cutoff were calculated; optimal cut-off was defined as the measured quantity which maximized sensitivity and specificity. For all analyses, differences were considered statistically significant at $p < 0.05$.

Sample size calculations

We wished to show that the AUC of 0.814 for the multi-biomarker model, based on a previous study, is significantly different from the null hypothesis value of 0.5.[7] Using a ratio of the sample between negative and positive cases of 113:46, significance at 0.05, and power of 0.8, we needed to study 23 survivors and 9 non-survivors, giving a total of at least 32 patients with COVID-19 to be studied.

Results

Throughout the 20-month study period, a total of 199 patients were screened for eligibility. Eleven (5.5%) of these 199 patients were excluded from the analysis due to incomplete data of the studied biomarkers. As such, we were left with 188 patients to be analysed, of which the outcome of in-hospital mortality was reached in 46 (23.0%) patients. These patients were classified as non-survivors in this analysis.

Table 1. Demographics, comorbidities, disease characteristics, and biochemical profiles

Variable		**Survivors (n = 142)**		**Non-survivors (n = 46)**		***p*-value**
Demographics						
Age		51	(31)	65	(13)	< 0.001
Gender	Male	75	51.0%	24	58.5%	0.394
	Female	72	49.0%	17	41.5%	
Ethnicity	Malay	137	93.2%	39	95.1%	0.656
	Non-Malay	10	6.8%	2	4.9%	
Comorbidities						
Comorbidities	No	88	59.9%	17	41.5%	0.036
	Yes	59	40.1%	24	58.5%	
Disease characteristics						
Stage	Stage I-III	82	55.8%	0	0.0%	< 0.001
	Stage IV-V	65	44.2%	41	100.0%	
Severity	Non-severe	80	54.4%	1	2.4%	< 0.001
	Severe	67	45.6%	40	97.6%	
Biochemical profiles						
WBC		5.90	3.84	7.16	7.79	0.013^
ANC		3.95	3.96	7.41	8.68	<0.001^
ALC		1.29	0.99	0.60	0.57	<0.001^

WBC: white blood cell; ANC: absolute neutrophil count; ALC: absolute lymphocyte count

Baseline characteristics

COVID-19 patients who died during admission were significantly older than those who went on to survive (Table 1). A significantly higher proportion of the non-survivors had baseline comorbidities compared to the survivors (Table 1). In terms of the COVID-19 disease characteristics, a higher proportion of the non-survivors presented at stage IV-V and with higher severity compared to the survivors (Table 1). In terms of biochemical profiles, the white blood cell count and absolute neutrophil count were significantly higher, while absolute lymphocyte count was significantly lower in the non-survivors compared to the survivors (Table 1).

For descriptive purposes, a significantly higher proportion of the non-survivors received general treatment of intubation, high-flow nasal cannula, non-invasive ventilation, do-not-resuscitate status, and ICU care in the first 24 hours of hospitalization, compared to the survivors (Table 2). Also, a significantly higher proportion of the non-survivors were given specific treatment of antibiotics, antiviral, steroid, and anticoagulant (Table 2).

Biomarker profiles

The median and interquartile ranges are shown for each of the three biomarkers as stratified by their in-hospital mortality status (Table 3). As a summary measure of predictive accuracy, we determined the AUC and the ideal cut-off values for the ability of each biomarker to classify patients with in-hospital mortality. As shown in Table 3, all biomarkers are significantly higher in the non-survivors compared to the survivors and are clinically valid in predicting in-hospital mortality, as indicated by the AUC > 0.7.

Derivation of the model

We then used binary logistic regression to combine all biomarkers to determine the combination's association with in-hospital mortality. The resulting logistic regression equation is logit (probability of in-hospital mortality) = -4.215 + (0.009 x CRP) + (0.003 x LDH) + (0.008 x NLR). The Hosmer-and-Lemeshow test was not significant ($p = 0.668$), indicating adequate calibration of the model.

Prognostic performance of the model

We found that the AUC of the combined biomarkers was 0.866 (95% CI 0.807–0.925, $p < 0.001$), which suggested a very good model discrimination. Of note, the AUC of the combined biomarkers is higher than its constituent individual biomarkers (Fig. 1), indicating better performance of the multi-biomarker approach in predicting mortality in COVID-19 patients compared to the single biomarker approach.

Table 2. General and specific treatments in the first 24 hours

Variable		**Survivors (n = 142)**		**Non-survivors (n = 46)**		***p*-value**
General treatment in the first 24 hours						
Intubated	No	146	99.3%	21	51.2%	< 0.001
	Yes	1	0.7%	20	48.8%	
HFNC	No	126	85.7%	26	63.4%	0.001
	Yes	21	14.3%	15	36.6%	
NIV	No	139	94.6%	31	75.6%	0.001
	Yes	8	5.4%	10	24.4%	
MV	No	145	98.6%	22	53.7%	< 0.001
	Yes	2	1.4%	19	46.3%	
DNR	No	141	95.9%	11	26.8%	< 0.001
	Yes	6	4.1%	30	73.2%	
ICU	No	139	94.6%	20	48.8%	< 0.001
	Yes	8	5.4%	21	51.2%	
Specific treatment in the first 24 hours						
Antiviral	No	128	87.1%	30	73.2%	0.032
	Favipiravir	19	12.9%	11	26.8%	
Antibiotic	No	60	40.8%	1	2.4%	< 0.001
	Yes	87	59.2%	40	97.6%	
Steroid	No	65	44.2%	0	0.0%	< 0.001
	Yes	82	55.8%	41	100.0%	
Anticoagulant	No	73	49.7%	2	4.9%	< 0.001
	Yes	74	50.3%	39	95.1%	

HFNC: high-flow nasal cannula; MV: mechanical ventilation; DNR: do not resuscitate; NIV: non-invasive ventilation

Table 3. Biomarker profiles

Biomarker	Survivors (n = 142)		Non-survivors (n = 46)		p-value*	AUC	Cutoff
	Median	IQR	Median	IQR			
LDH (U/L)	**511**	**329**	**973**	**814**	**< 0.001**	**.824**	**380**
CRP (mg/L)	18.0	65.0	96.0	148	< 0.001	.760	25
NLR	2.76	4.43	9.97	19.22	< 0.001	.830	1.83

LDH: lactate dehydrogenase; CRP: C-reactive protein; NLR: neutrophil-to-lymphocyte ratio, AUC: area under the curve

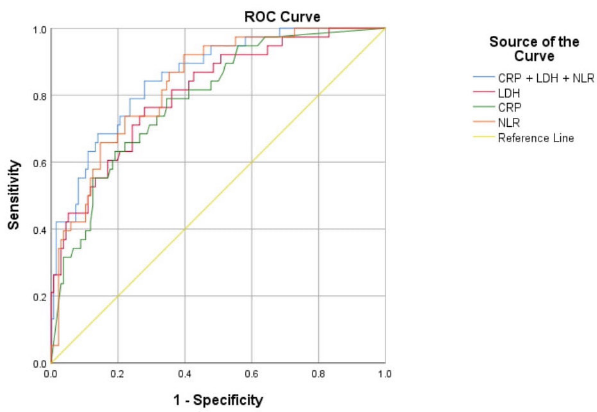

Fig. 1. Receiver-operating characteristic curves of the multi-biomarker model compared to its constituent individual biomarkers for their mortality predictive performance. CRP: C-reactive protein; LDH: lactate dehydrogenase; NLR: neutrophil-to-lymphocyte ratio.

Discussion

In this cross-sectional study, we assembled a cohort of 188 hospitalised COVID-19 patients and studied three biomarkers on their admission with the overall goal of deriving a multi-biomarker model that would allow discrimination of those who are at increased risk of in-hospital mortality. A multi-biomarker model using baseline CRP, LDH, and NLR predicted in-hospital mortality with a very good performance in our hospitalised COVID-19 patients. Of note, the multi-biomarker outperformed its constituent individual biomarkers in predicting in-hospital mortality in our COVID-19 cohort.

We believe that our results are novel with respect to the combined use of CRP, LDH, and NLR, each of which represents different aspects of the host inflammatory response to COVID-19 infection. At present, the pathophysiological process of COVID-19 infection is not fully understood. However, it is likely that the disease represents a complex interplay between various inflammatory responses rather than a singular type of response to the infection. As such, a multi-biomarker model that corresponds to various possible inflammatory processes is a logical approach in the prognostication of the disease.

Emerging evidence suggests that the multi-biomarker approach shows promising results in predicting the outcome of COVID-19. For example, Smilowitz *et al.* demonstrated that combination of three biomarkers (cardiac troponin, d-dimer, and CRP) yielded an improvement in the AUC of a clinical model from 0.765 to 0.879.[8] In another study, Zhou *et al.* found that combination of interleukin-6, neutrophil count, and natural killer cells had a high prediction accuracy for mortality in the training data as well as in the independent data of hospitalised COVID-19 patients.[9] Another study by Wang *et al.* using a multiplexed proteomics assay of up to 50 peptides derived from 30 known and newly introduced COVID-19-related protein markers predicted death with an accuracy of 0.76, which outperformed compound clinical risk assessment such as the Sequential Organ Failure Assessment score and the Acute Physiological and Chronic Health Evaluation II score.[10]

The strength of this study is the ability of our multi-biomarker model to predict an objective, rather than a subjective endpoint, namely in-hospital mortality, in the patients who would not necessarily be regarded as high-risk, *i.e.*, patients with Stage I to III COVID-19. All three biomarkers used are routinely available across many centres, and therefore usage of the multi-biomarker model is feasible to be applied in daily clinical settings. Also, all blood samples were collected within 24 hours of hospital admission, making the study reproducible while generating a prediction system that can be used from as early as the first day of hospital admission.

Although our results are encouraging, this study has several limitations. First, due to the retrospective nature of our study design, other biomarkers that could have performed well were not analysed, including other acute phase reactants such as albumin and ferritin. Second, the multi-biomarker model that we derived predicted our single-centre data set, but whether it is generalisable to external population is unknown. Third, our multi-biomarker model will require validation on an independent data set, ideally in a prospective study. Last, because this study used a convenience sampling method, selection bias may have led to a non-representative population. Therefore, further research is warranted to validate the clinical utility of our multi-biomarker model in the prediction of mortality in COVID-19.

Conclusion

Our study suggests that CRP, LDH, and NLR have positive associations with mortality in COVID-19. A multi-biomarker model using a combination of these individual biomarkers adequately predicted in-hospital mortality and outperformed its constituent individual biomarkers in our hospitalised COVID-19 patients. As such, a simple multi-biomarker approach using basic laboratory parameters of CRP, L and NLR is a potentially reliable to aid in the prognostic of COVID-19 patients, although this requires further validation in a prospective study.

Declarations

Ethics approval and consent to participate

This cross-sectional study was conducted after receiving ethical approval from Universiti Sains Malaysia Human Research and Ethics Committee (USM/JEPeM/21100653). Request of the waiver of written informed consents was granted given that the study involved retrospective chart review of the subjects.

Competing interests

Dr. Wan Fadzlina Wan Muhd Shukeri serves as Section Editor for Malaysian Journal of Anaesthesiology. She has 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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Retained epidural catheter: an update

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Abstract

The retained catheter fragment is a rare complication when performing epidural techniques. There is a paucity of studies available, with Australian data quoting an incidence of 1 in 60,000. For this article, we reviewed 36 case reports of retained epidural catheters between 1995 and 2020. The case reports found computed tomography scans to be the most reliable modality to investigate a retained epidural catheter. The decision to surgically remove or treat conservatively should be multidisciplinary with most operations involving symptomatic or long fragments. In our review, we found 25 (69.4%) reports of surgical removal, with 21 opting for immediate removal. Conservatively treated retained fragments should be monitored for neurological or infective complications. Patients should receive a follow-up plan and be educated regarding red flag symptoms to facilitate further management. For future reference, a detailed documentation of the incident, parties involved, discussions, and decisions should be made.

Keywords: anaesthesia, complications, retained epidural catheter, surgical intervention

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Introduction

The retention of an epidural catheter brings about significant distress to patient and doctor. A retained epidural catheter can occur as a result of shearing through the Touhy or fracturing of the catheter due to excessive traction upon removal. Inert and rarely causing complications, it commonly poses psychological and possible litigative implications rather than neurological deficit or permanent disability. The purpose of this review article is to facilitate decisions and clinical management of a retained epidural catheter.

Incidence

The incidence of a retained epidural catheter is rare, occurring 1 in 60,000 catheters based on Australian data.[1] Due to its infrequency, there is a paucity of experimental studies, randomised control trials, or meta-analyses regarding this subject. For the purpose of this article, we reviewed 36 case reports between the years 1995 to 2020. Epidurals were commonly placed in obstetrics, with 14 cases of labour analgesia and 1 case of Caesarean section (41.7%). There were 7 (19.4%) gynaecological cases including 4 hysterectomies, and 7 (19.4%) orthopaedic cases including 5 arthroplasties. Other disciplines included 4 (11.1%) urological cases, 3 (8.3%) from general surgery including 2 of which were from hepatobiliary. 22 (61.1%) cases involved solely an epidural for analgesia or anaesthesia, 10 (27.7%) combined with spinal anaesthesia, and the remaining 4 cases (11.1%) as a supplement to general anaesthesia.

Potential mechanisms and risk factors

From our review, 15 (41.6%) catheters were retained during removal,[2-16] and 8 (22.2%) catheters could not be removed due to knotting.[17-23] Knotted catheters mostly involved excessive lengths threaded during insertion ranging 4 to 17 cm with a median length of 7 cm. We found 5 (13.8%) cases whereby a fragment was sheared off as a result of being cut by the Touhy needle as it was withdrawn through it[24-28] and 4 (11.1%) cases of fragments fracturing from excessive force during extraction together with the Touhy needle.[16,29,30] There were 2 cases where the retained catheters were incidental findings many years after insertion[31,34] and 1 case of migration to the paravertebral space.[33]

Radiological investigation

Computed tomography (CT) is the recommended method of radiological investigation to detect the presence and location of a retained catheter.[7,10,26] In our review, 9 CT scans were performed with 7 (77.8%) scans correctly identifying the catheter.[7-13,26,27] However, the radio-opaque nature of most catheters would justify a simple radiograph in the absence of CT scan. All 6 case reports where X-rays were performed located the catheter. Magnetic resonance imaging (MRI) scans appeared less reliable, with the 6 scans performed only locating 4 (66.6%) retained fragments. Additionally, burns and migration are also a concern during MRI scans, especially with wire-reinforced catheters.

Decision for surgical removal

Indications for surgical removal include intrathecal migration, neurological symptoms, or an exposed fragment potentially forming a channel for infection. However, conservative treatment for asymptomatic patients has been reported. There is a lack of evidence regarding timing of surgery with potential migration, adhesions, and scar formation complicating delayed removal. In our review, we found 25 (69.4%) cases of surgical removal, with 21 opting for immediate removal. Timing of delayed removal ranged from 7 months to 12 years with equivocal surgical difficulty.[6,28,31,34] The option for surgical removal, timing of surgery, or conservative treatment should involve a multidisciplinary decision between Anaesthesia, Spine/Orthopaedics, and Neurosurgery to weigh the risks and benefits of each treatment option for the patient.

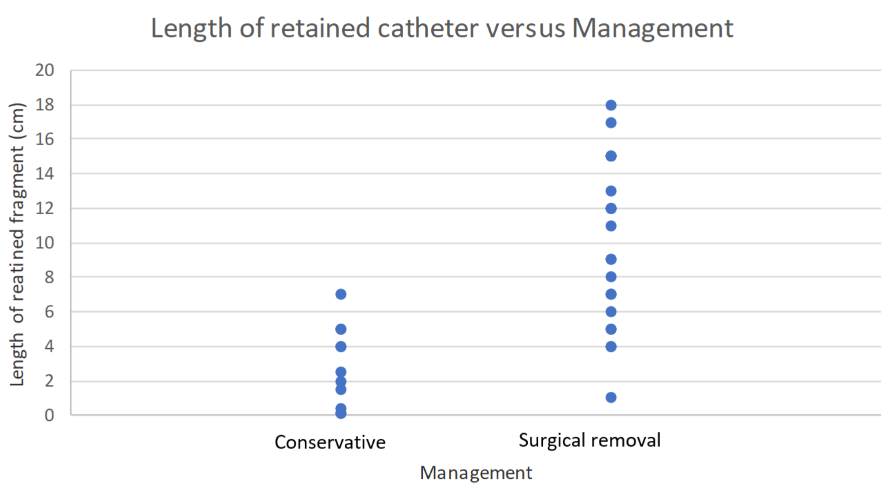

Fig. 1. Scatterplot of length of retained catheter versus management.

Table 1. Factors regarding surgical removal of a retained epidural catheter

Surgical removal	Conservative treatment
Exposed catheter fragment acting as fistula/ channel[17-23] Symptomatic fragment[5,26,28,34] Retained length > 5 cm Intrathecal migration Patient preference	Complications are rare Asymptomatic fragment Avoids complications of major surgery[13,30] Small retained fragment

Table 2. Red flag symptoms of a retained epidural fragment

Symptoms to look for
Lower back pain Palpitations and pallor Paraesthesia (numbness) Convulsions (fitting) Swelling, bogginess and erythema at insertion site Transient or permanent paralysis Radicular pain migrating to legs Urinary /bowel incontinence Headache Signs of infection, *e.g.*, fever

There were 10 (27.8%) catheters externally exposed due to knotting or migration, 4 (11.1%) cases with neurological deficit,5,26,28,34 [5, 26, 28, 34] and 1 case of fragment migration during follow-up for conservative treatment.[6] The remaining surgeries were due to the patient's preference in 3 (8.3%) cases, with 11 case reports not stating the indication for surgery. From our limited evidence, conservative management tends to involve fragments < 5 cm, as illustrated in Figure 1.

Spine surgery is not without its own complications, with 1 case of surgical site infection[13] and 2 cases of transient postoperative lower back pain treated with physiotherapy.[30,34] From our review, factors that may influence the decision to operate have been summarised in Table 1.

The decision to leave the retained epidural catheter in situ should be accompanied by a detailed explanation of a follow-up plan to the patient and family. This should include symptoms of catheter-related complications as outlined in Table 2,[5] including advice to seek immediate medical attention in the event of a symptomatic fragment. An information card warning of the presence of the retained fragment with red-flag signs stated therein can be given to the patient. We recommend following patients up a month after discharge with subsequent intervals ranging between 6 months up to annually, with eventual discharge if they remain asymptomatic thereafter. A detailed documentation of the incidence, discussion, and decisions should be made for future reference. A flowchart that summarises our suggested management algorithm is included as Appendix 1.

Potential preventive measures

Several articles have suggested preventive measures for a retained epidural catheter. Experience and skill are of utmost importance, be it in the operator or supervisor role. In cases of multiple attempts, the catheter should always be withdrawn together with the Touhy needle to prevent shearing. During removal, a continuous low-force traction limits strain on the catheter and may prevent breakage. In the event of catheter stretching, stopping and allowing a few hours' grace period before reattempting can help prevent fracturing of the catheter. Slow injection of a saline bolus through the catheter may free it from surrounding tissue entanglements.[2,31] Patient positioning can improve removal success rates, with a lateral decubitus position or the position previously adopted during insertion potentially reducing the force required during removal.[35] However, these manoeuvres come with the caveat that there is a paucity of evidence to support their efficacy and should be utilised with caution.

Conclusion

A retained epidural catheter is a rare and distressing occurrence. Surgical removal should be a holistic multidisciplinary decision considering the clinical factors and patient's wishes. Patient education and follow-up are hallmarks of conservative management in the asymptomatic patient.

Declarations

Ethical approval and consent to participate

Not required

Competing interests

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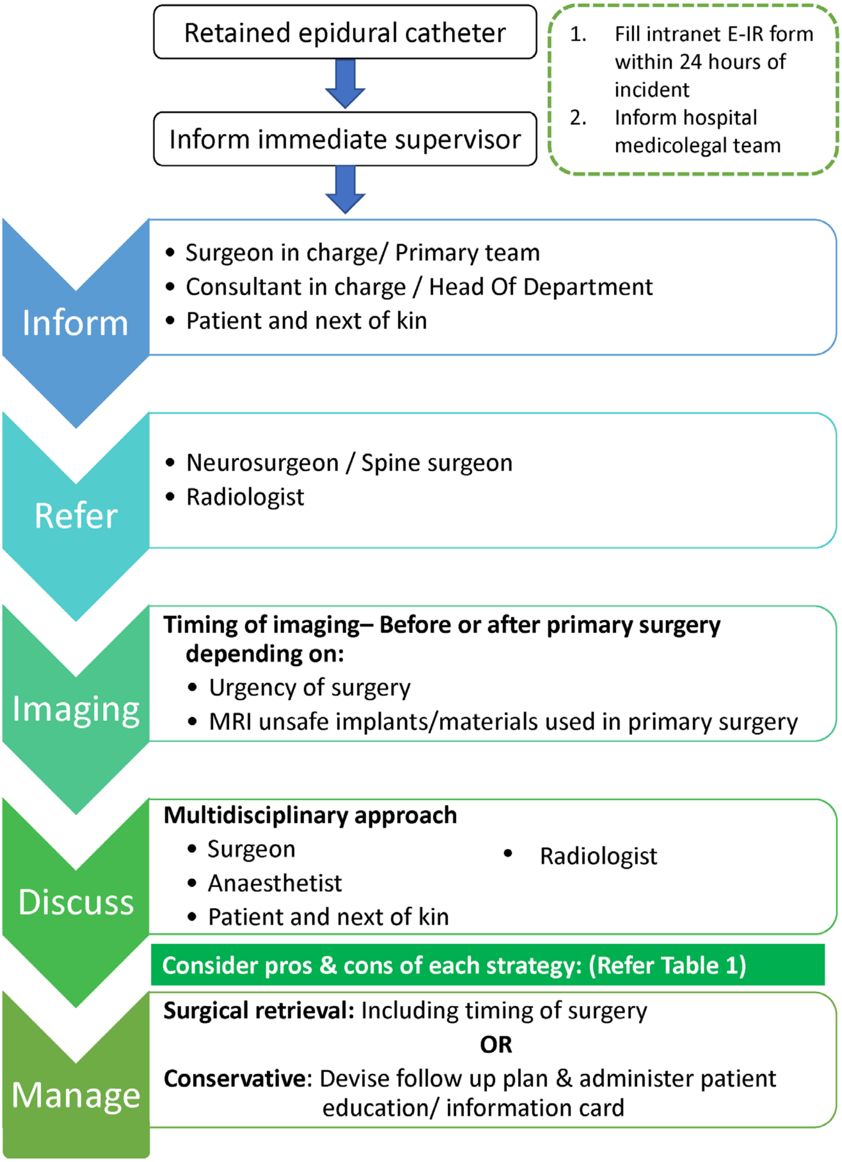
Appendix 1

Retained Epidural Catheter Management Flowchart



This flow chart acts as a guide for the systematic management of a retained epidural catheter. Clinicians should apply it with discretion based on individual scenarios.

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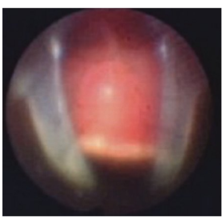

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Green anaesthesia: a review of sustainable perioperative practices and the potential application in Malaysia

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Abstract

Global warming and worsening climate change threaten environmental sustainability and exacerbate disease burdens worldwide. Alarmingly, the healthcare sector emerged as a substantial contributor to this crisis. The operating theatre significantly contributes to hospital waste and greenhouse gas emissions. Anaesthesiologists are morally compelled to combat this crisis, aligning with our oath as physicians of "first, do no harm," ensuring patient safety extends beyond the operating room by advocating for sustainable practices that safeguard both health and the environment. Understanding the climate change indicators reveals the alarming impact of human actions on escalating greenhouse gas emissions and their dire repercussions, such as global temperature shifts, severe weather events, and heightened natural disasters.

Greener solutions and adaptive policymaking are essential to address procurement, greenhouse gas emissions, and waste management challenges in health care settings. Anaesthesiologists should collaborate with surgeons and hospital management to navigate patient-specific issues analysing the environmental impact of hospital visits, investigations, and comorbidities. Efforts toward sustainable healthcare practices in the preoperative setting, such as telemedicine

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adoption, promoting eco-friendly transportation, and optimising patient health before surgery should be encouraged.

Anaesthesiologists should focus on the environmental impact of anaesthesia drugs, medical equipment, and electricity usage on the environment. We should be more responsible and able to justify our practices concerning the ecological implications of inhaled anaesthetic gases, propofol disposal, plastic-based equipment, and energy demands in operating rooms. The emphasis lies on adopting the 6Rs—rethink, refuse, reduce, reuse, recycle, and research—within anaesthesia practices to minimise environmental footprints.

Keywords: anaesthesia, climate change, recycle, reduce, reuse,

Introduction

Climate change cannot be overlooked and ignored. Every year, the planet's temperature increases, and the rate of increase has doubled since 1981 at an average rate of 0.18 °C per decade.[1] Worldwide, there are more than 250 million general anaesthetic procedures performed for surgery annually.[2] It has been shown that anaesthesia contributes substantially to greenhouse gas (GHG) emissions, as it is an equipment- and waste-intensive specialty.[3] Thus, anaesthesiologists carry an ethical imperative beyond patient care of enhanced recovery after surgery and ensuring patient safety. We are entrusted as custodians of the environment; owing to the nature of our working environment, we profoundly impact patient health, community well-being, and societal equilibrium. This ethical responsibility extends beyond the operating room, intertwining patient care with environmental stewardship. Therefore, to proactively be involved in the sustainable practice of anaesthesia, we need to understand the science evolving on climate change globally. This review will contextualize the basic changes in climate change, evidence-based sustainable perioperative practices, and their potential application in Malaysia.

Basic changes in climate and the effect on future population health

The global climate is a complex system. Climate change refers to the long-term shifts in local, regional, or global temperature and weather patterns, which occur either naturally or due to anthropogenic factors.[4] In an attempt to provide a large-scale overview of the dynamic global climate system, the World Meteorological Organisation (WMO) has listed seven key indicators that include surface temperature, ocean heat content, ocean acidification, glacier mass balance, sea ice extent, sea level, and GHGs.[5] These climate indicators are used as the global framework to monitor the four domains that are most relevant to climate change (temperature and energy, atmospheric composition, ocean and water, as well as cryosphere).[6,7] Changes in atmospheric composition, *i.e.* increasing levels of GHGs, are of greatest concern due to the vulnerability to human influences and its widespread impact on the other three domains.[8]

Global GHG emissions have been increasing continuously since the 1900s.[7] Human activities have contributed greatly to the rising levels of GHGs in the atmosphere and have become the major driver of climate change. In 2021, the atmospheric concentration of carbon dioxide, the predominant GHG, increased by 149% compared to pre-industrial levels.[7] Other major GHGs such as methane and nitrous oxide have also increased by 262% and 124%, respectively, compared to pre-industrial levels.[7] The causes of increasing GHG emissions include power generation, manufacturing, deforestation, transportation, agriculture, and excessive power consumption.[4] GHG emissions are a major driver of global warming and climate change. The global surface temperature increases over time, resulting in extreme weather, rising sea levels, reduced biodiversity, food shortages, and heightened challenges such as health risks and poverty.[4]

In 2022, a total of 272 recorded natural disasters were held accountable for 76,125 deaths, affected another 185 million people, and caused total (adjusted) damage that cost approximately USD 209 billion.[9] More than 90% of the documented natural disasters were potentially associated with global warming and climate change (drought, extreme temperature, flood, landslide, storm, and wildfires).[9] The impact of climate events on humanity depends on the vulnerability of the population and the preparedness of the community.[10] Extreme weather and natural disasters are known to adversely affect human health, both physically and mentally, as well as posing higher risks to health systems. The population, especially vulnerable ones such as older people or lower-income communities, faces greater risks of injuries and infections, exacerbated non-communicable diseases, as well as increased need for health care services post-disaster.[10,11] Based on the projected trend of GHG emissions, a predictable increase in the frequency and intensity of extreme climate events is foreseen in the coming decades.[7] Therefore, to minimise the negative impacts of climate hazards on population health, the building of climate-resilient health systems should be the main focus for policymakers and stakeholders. Climate adaptation and mitigation plans adequately supported by disaster risk management are essential to prepare health systems to manage health impacts associated with extreme climate events.[10,12]

Climate change presents contradictory challenges for the healthcare sector. Extreme climate events impact the population's health and increase the demand for health care services.[10,11] However, it is important to note that the health care sector is a large-scale and important socioeconomic sector and therefore is a significant contributor to GHG emissions itself, which eventually may lead to more climate hazards. On average, global health care is accountable for 5% of total GHG emissions (carbon dioxide equivalent).[11,13,14] This figure is equivalent to approximately one-fifth of the GHG emissions from the food and agricultural sectors.[11] Among the various GHGs, anaesthetic gases contribute from 0.01% to 0.1% of total emissions.[15] In addition to GHG emissions, increasing medical waste production is also one of the major sustainability shortfalls in health care. Operating rooms contribute to approximately 30% of daily medical waste, 25 % of which was attributable to anaesthesia practices.[16] A notable lack of awareness and commitment to "greener" solutions in health care, as well as anaesthesia practices, has warranted an increased effort to enhance research and policymaking to improve sustainability in the healthcare sector.

Preoperative environmental concerns

In the global pursuit of sustainable healthcare practices, the preoperative setting has emerged as a crucial arena for reducing the environmental footprint. The preoperative issues affecting global climate change can be discussed according to organizational and patient factors.

General and organisational issues

Shortcomings in the procurement process

Health care procurement typically revolves around seeking immediate financial advantages, often leaning heavily on cost-effectiveness. This prioritisation tends to overshadow the consideration of long-term environmental implications associated with purchasing pharmaceuticals and medical equipment. There is a prevalent misconception favouring disposable items due to their perceived lower initial costs and maintenance expenses compared to reusable alternatives. However, this perspective fails to account for the broader environmental impact and the extended costs over the life cycle of the products.[17]

Upstream greenhouse gas emissions

The majority of GHG emissions are prevalent upstream in the supply chains of health care services, particularly within hospitals where pharmaceuticals and medical equipment are procured. These emissions originate from various stages of the supply chain, spanning the production, transportation, and distribution of pharmaceuticals and medical supplies. The processes significantly contribute to the overall carbon footprint of health care institutions.[18] Gathering intricate environmental data on these products remains challenging. Companies often withhold critical manufacturing details necessary for exhaustive Life Cycle Assessments (LCAs), making it hard to gauge their true environmental impact. Conducting LCAs demands considerable expertise and financial investment, contributing to the complexity of integrating environmental considerations into procurement decisions.

Lack of institutional support and training

In a recent nationwide survey conducted among Canadian anaesthesiologists, several prominent barriers were identified that hindered effective sustainability practices. The survey highlighted key challenges, including limited support from hospital leadership (63.5%), insufficient knowledge levels (62.8%), indifferent staff attitudes (52.2%), and inadequate recycling facilities (51.5%).[19] Similar sentiments were echoed by anaesthesiologists in Malaysia during a recent nationwide survey, citing challenges such as lack of recycling facilities as the most significant obstacle, followed by the absence of support from hospital or operating theatre (OT) leadership, staff attitudes, and insufficient funding.

A research investigation discovered that nearly 92% of solid waste generated during surgeries was not properly sorted and ended up being treated as biohazardous material unnecessarily.[20] Another revealing survey conducted by the American Society of Anesthesiologists found that 56% of respondents incorrectly labelled items in contact with patients as biohazardous waste.[21] These findings underscore a significant lack of awareness among medical professionals regarding proper waste management protocols.

Patient-specific issues

Hospital visits and investigations

The journey patients undertake before surgery involves several hospital visits for assessments, clinic appointments, and numerous investigations. This not only strains their time and finances but also contributes to environmental impacts due to increased transportation. Patients traveling from distant locations encounter even more challenges due to the extended travel and additional logistical considerations. Many a time, when patients arrive from other health care facilities, inadequate or missing medical records often send health care providers on a scavenger hunt, wasting precious time in retrieving vital information. Moreover, this absence of comprehensive, centralised, and retrievable data often prompts health care professionals to reorder a battery of tests and examinations, from X-rays to blood work, adding unnecessary financial strain and environmental impact through duplicate procedures.

Comorbidities
Insufficient optimisation of a patient's health before surgery not only burdens the health care system but also amplifies its environmental impact.[22] Longer hospital stays and increased use of resources translate into higher energy consumption, greater waste generation, and elevated emissions. Additionally, postoperative complications often necessitate further interventions, leading to more medical procedures, which in turn contribute to additional environmental strain. This collective impact underscores the interconnectedness between health care practices, patient well-being, and environmental sustainability.

Sustainable preoperative practices and potential applications in Malaysia

Efforts toward sustainability in health care often encompass initiatives at two distinct but interrelated levels: institutional or organisational endeavours and patient-specific measures.

Institutional or organisational endeavours

Procurement and life cycle analysis
The foundation of understanding a product's environmental impact lies in the LCA methodology, crucial in gauging its effect on the environment from creation to disposal (cradle-to-grave impact). This detailed approach dives into the raw materials, energy use, emissions, and waste generated throughout a product's life stages, helping us evaluate its environmental effects comprehensively.[23] Applying LCA to procurement decisions in Malaysia's health care sector can be transformative. It allows for informed choices based not only on a product's efficacy and cost, but also on its environmental implications. For instance, in the acquisition of medical equipment or pharmaceuticals, LCA can provide insights into each item's

environmental footprint, enabling hospitals and health care facilities to prioritise products with lower ecological impacts. Furthermore, leveraging LCA facilitates a deeper understanding of a product's overall cost to the healthcare system. This goes beyond the initial purchase expense, encompassing disposal, sterilisation, and potential repackaging costs for reusable items. By integrating life cycle costing into procurement strategies, institutions can identify environmentally sustainable alternatives that are also cost-effective in the long run. However, applying LCA in procurement in Malaysia comes with challenges. Access to comprehensive data and information on the environmental impacts of products, especially proprietary manufacturing details, might be limited. Additionally, conducting thorough LCAs requires specialised expertise and resources, which might not always be readily available.

Initiatives that exert pressure on sales representatives to supply LCA data can trigger a shift in the health care industry towards eco-conscious procurement. This encourages pharmaceutical and equipment companies to focus on evaluating and publishing the environmental assessments of their products. It may prompt them to optimise production processes, striving for more environmentally competitive options.[24]

Institutional support and education

Numerous sustainability initiatives transcend the confines of a singular department, posing a challenge for any individual service to claim ownership over such expansive projects. Collaborative 'green teams' composed of perioperative services and a diverse range of health care professionals and support staff play a pivotal role in addressing sustainability challenges.[25] We as anaesthesiologists should actively spearhead hospital green teams and leverage our clinical expertise to initiate recycling programs and implement sustainable waste management practices. Each hospital can form a dedicated sustainability committee that brings together influential decision-makers, including:

1) Senior leaders, who are empowered to approve capital investments and equipment purchases.

2) Representatives from crucial support services such as Facilities, Environmental Services, and Procurement, who are entrusted with managing the operational framework for sustainability practices.

3) A designated sustainability officer responsible for driving environmental initiatives and compiling pertinent statistics.

4) Multidisciplinary clinical champions encompassing frontline health care providers, surgeons, anaesthesiologists, and nurses. Their voluntary involvement facilitates communication between environmental services and various departments. They also coordinate staff education and action plans.

Securing support from senior leadership is crucial in the Malaysian context for the success of organisational-wide sustainability initiatives. When top level executives genuinely endorse and prioritise sustainability within the organisation, these values permeate the organisational culture, fostering a collective embrace of pro-environmental behaviours among all staff members.

Increasing awareness and offering comprehensive education and training are vital components for successful environmental sustainability in health care. Implementing structured training sessions for waste management, sustainable procurement, and energy efficiency is crucial. Regular audits and adopting sustainability efforts as part of hospital or departmental quality improvement projects reinforce these practices, fostering a culture of environmental responsibility among health care professionals.

Patient-specific measures

Technological innovations for preoperative visits

Tackling patient travel is crucial in reducing health care institutions' carbon emissions. In Malaysia, innovative strategies can be applied to address this issue and create a positive impact. The COVID-19 pandemic acted as a catalyst for the adoption and acceleration of telemedicine practices worldwide, including in Malaysia. Embracing telemedicine practices can significantly reduce the need for patients to physically travel to health care facilities for preoperative consultations, routine check-ups, and follow-up appointments. This technology allows health care providers to offer remote consultations, minimising travel-related emissions and reducing the burden on patients, especially those residing in rural areas.[26] However, the major challenge in fully implementing telemedicine lies in infrastructure limitations. In remote or underserved areas, inadequate internet connectivity or technology access can hinder effective telemedicine adoption. Also, the diversity of platforms and technologies used for telemedicine creates interoperability challenges and could lead to data privacy and security concerns. These are things we need to investigate to ensure the success of telemedicine.

The Malaysian health care system should investigate adopting electronic medical records EMRs across states or nationwide to enhance efficiency and accessibility while reducing the necessity for patients to carry physical records. It streamlines the health care process, curbing unnecessary trips for medical data retrieval as well as redundant investigations and testing.[27] Implementing EMRs faces various challenges, including initial costs for system setup, data migration from existing records, and staff training for seamless integration. Security concerns regarding patient data privacy and interoperability issues between different EMR systems also hinder their smooth adoption.

Investing in and promoting eco-friendly modes of transportation, such as improving public transit networks and establishing bicycle facilities, can significantly reduce carbon emissions. Hospitals can encourage staff and patients to use public transportation or cycling by providing adequate facilities, such as bike racks and designated lanes, or promoting public transit incentives.[17]

Premorbid optimisation

The proactive involvement of primary care teams and general practitioners in identifying and addressing patients' pre-existing health concerns is crucial. Initiating measures such as early blood pressure and sugar control, supporting smoking and drinking cessation, and beginning rehabilitation can significantly enhance a patient's condition before surgery, leading to better outcomes. This not only reduces hospital resource usage and length of stay but also contributes to environmental sustainability by cutting down on overall healthcare impact.

Intraoperative sustainability practices and potential applications in Malaysia

The environmental impact of intraoperative services managed by anaesthesiologists is substantial, primarily due to the frequent utilization of drugs, medical equipment, and electricity. The global climate changes contributed by intraoperative anaesthesia will be discussed along these lines.

Anaesthesia drugs

Inhaled anaesthetic gases

General anaesthesia comprises a delicate equilibrium between narcosis, analgesia, and muscle paralysis. Inhaled anaesthetic gases (IAGs) such as sevoflurane and desflurane are usually primarily employed to induce narcosis. However, the implications of utilising IAGs extend beyond the operating room. These IAGs have a discernible impact on our climate through multiple pathways. They play a role in exacerbating global warming and contribute to ozone layer depletion.[28] The measurement of their influence is often quantified using the concept of Global Warming Potential (GWP). GWP evaluates the comparative warming effect of a gas over a specified duration, typically 100 years, in contrast to carbon dioxide, the benchmark unit for global warming. The potency of inhaled anaesthetics as GHGs is striking. Desflurane, for instance, exhibits a staggering GWP100 of 2540, denoting its 2540-fold contribution to global warming compared to carbon dioxide. Similarly, isoflurane and sevoflurane register GWP100 of 510 and 130, respectively.[29] To illustrate, in the United States, emissions from inhalational anaesthetic agents measured with a GWP100 comparison equate to the annual output of a coal-fired plant or the collective emissions of nearly 1 million automobiles annually.[30]

The addition of nitrous oxide to volatile agents will reduce the amount of other volatile agents needed to deliver one minimum alveolar concentration hour of anaesthetic. However, nitrous oxide has an ozone depletion property, a GWP100 of 248, and an atmospheric life span of atmospheric life of 114 years. In comparison, the atmospheric lifetimes of isoflurane, sevoflurane, and desflurane are, respectively, 3.2, 1.1, and 14 years.[31,32]

Propofol

Intravenous anaesthetic drugs significantly contribute to global waste and subsequent pollution through various avenues. The disposal of unused drugs, along with the vehicles for drug administration, *e.g.*, plastic syringes, needles, and tubing, contributes to medical waste. Packaging materials comprising plastic, paper, and glass further compound the environmental impact. The environmental toxicity of drugs can be evaluated using the Swedish Chemicals Agency classification system for aquatic pollutants. This system, known as PBT, evaluates a drug's persistence (P), potential for bioaccumulation (B), and toxicity (T) upon release into the environment.[33] Unfortunately, conventional wastewater treatment plants are ill-equipped to eliminate pharmaceuticals, leading to their discharge into surface water bodies and subsequent contamination.

Among the most utilized and wasted drugs in anaesthesia is propofol.[34] It consistently ranks among the highest in the PBT index for drugs used in anaesthesia with a PBT of 9, as compared to atracurium with a PBT of 3.[35] It often finds its way into sewage systems via disposal practices. Propofol's resistance to biodegradation in water and its toxicity to aquatic organisms lead to inhibition of algae growth and acute harm to small crustaceans and freshwater fish.[36]

Equipment

Medical waste constitutes 4% of the total plastic waste globally.[16] In the landscape of anaesthesia practice, the importance of infection control since the COVID-19 era has further increased reliance on disposable single-use equipment, significantly made from various plastic materials. However, this trend comes with ecological repercussions as plastics, a main component of essential tools like supraglottic airway (SGA) devices, laryngoscope blades, facemasks, circuits, oxygen tubing, and personal protective equipment, resist decomposition and biodegradation. The life cycle of these plastics inflicts considerable harm on our environment and human health, perpetuating GHG emissions and polluting air, water, and soil.

Electricity

Sustainability in anaesthesia encompasses not only equipment and waste management but also addressing the substantial energy demands within operating rooms. These spaces are significantly more energy-intensive per square foot than the rest of the hospital due to stringent heating, ventilation, and air conditioning (HVAC) needs, extended hours of lighting, patient monitoring devices, and specialized air handling units (AHUs). AHUs play a vital role in maintaining sterile environments to reduce the risk of wound contamination and infections.

The source of obtaining the energy to generate electricity is also paramount. Hydropower is the most efficient way to generate electricity. Modern hydroturbines can convert as much as 90% of the available energy into electricity as compared to fossil fuel plants, which are only approximately 50% efficient.[37] Obtaining a source of energy from hydroelectric is cleaner than obtaining the energy required from coal.

Sustainable perioperative practices and their potential application in Malaysia

In practicing sustainable perioperative practices, the use of the 6Rs (rethink, refuse, reduce, reuse, recycle, and research) in our daily work is imperative.

Rethink

Given the substantial greenhouse effects associated with volatile agents in general anaesthesia, reconsideration of these agents is imperative. Opting for volatile agents with lower GWP100, where viable and safe for patients, becomes a responsibility. Prioritizing the use of such agents in the absence of contraindications aligns with our ethical duty to mitigate environmental impact while ensuring optimal patient care during anaesthesia. This shift in selection criteria for volatile agents underscores our commitment to eco-conscious anaesthesia practices.

Whether regional anaesthesia should be the primary anaesthesia technique when possible is still uncertain. A LCA on administering general anaesthesia using sevoflurane or total intravenous anaesthesia (TIVA), or administering spinal anaesthesia with intravenous sedation had similar carbon footprint production.[38] However, the same study suggested a lower carbon footprint is emitted when low-flow gases are used for general anaesthesia, either with sevoflurane or TIVA. Thus, we should consciously practice low-flow anaesthesia with the appropriate equipment and monitoring. In addition, this study also found that reducing single-use plastics and collaborating with engineers to augment energy efficiency are more beneficial in reducing the carbon footprint than choosing between regional anaesthesia or TIVA over general anaesthesia with sevoflurane.

Refuse

Although nitrous oxide remains prevalent in Malaysian practice due to its efficacy in reducing volatile agent usage for anaesthesia, its climate impact prompts refusals. Embracing alternatives becomes imperative, *e.g.*, leveraging patient electroencephalogram readings to monitor the state of narcosis such as utilising the bispectral index (BIS) during anaesthesia. Research highlights BIS-guided anaesthesia's efficacy in curbing unnecessary anaesthetic exposure by adjusting drug consumption based on BIS values.[39] Implementing strategies such as BIS monitoring enables precise dosing, presenting a tangible step towards environmentally conscious anaesthesia practices. This tailored approach enhances patient safety and minimizes volatile agent administration.

Reduce and recycle

As plastics are non-recyclable and non-biodegradable, a heightened consciousness is warranted when accessing plastic-made equipment. It is crucial to minimize routine drug preparation and syringe usage. Prioritizing the minimum essential syringes and refraining from opening emergency drugs unless necessary while ensuring immediate accessibility proves prudent. A recent quality improvement initiative in our centre showcased significant cost savings by abstaining from opening and diluting emergency drugs over two months.[40] This approach not only preserves resources but also aligns with sustainability objectives. Such findings underscore the financial benefits and ecological responsibility gained by judiciously managing plastic-based equipment and drug utilisation in anaesthesia practices.

Mitigating electricity consumption in the OT involves proactive measures, *e.g.*, powering down OT lights, air-conditioning units, and idle equipment and monitors. Concurrently, minimizing avoidable waste production within the OT is essential. Collaborative initiatives between the OT team, hospital management, and Biomedical Engineering units can facilitate the reprocessing of devices, ensuring their safety and, when feasible, recycling the waste. This collaborative approach aligns with sustainability objectives, fostering responsible resource management and waste reduction within anaesthesia practices. By embracing these strategies, anaesthesia teams contribute to a more eco-conscious healthcare environment while optimizing operational efficiency and resource utilization in the OT.

Reuse

Achieving sustainable anaesthesia practices entails a delicate balance between infection control and reducing the carbon footprint, often necessitating a choice between single-use and reusable equipment. Collaborating closely with hospital infectious disease units becomes paramount to align practices with local guidelines for optimal outcomes. LCA on certain equipment such as SGA devices and anaesthetic drug trays showed that reusing them leads to lower carbon footprints.[41]

However, the assumption that reusing equipment always reduces the carbon footprint is not universal. For instance, in Australia, the carbon footprint of reusable equipment can slightly surpass that of single-use counterparts due to greater water consumption in the cleaning process.[42] This challenges the conventional belief, highlighting the intricate considerations for sustainable choices. We should encourage our government to use cleaner energy sources such as hydroelectric and wind turbines. In addition, cost-efficient use of water supply to clean our OR equipment should be emphasized among our health professionals.

Unused equipment holds the potential for donation to suitable areas, aiding education and skill development. Expired equipment, for instance, can enrich medical school clinical skills labs, offering students valuable practice opportunities. Such donations foster learning environments and repurpose unused resources for educational advancement, benefiting aspiring health care professionals in their training and skill development.

Research

A significant portion of anaesthetic gases administered during surgery is exhaled by patients, escaping into the atmosphere via scavenging systems. This release contributes to greenhouse effects and ozone depletion. Current research focuses on recycling these exhaled anaesthetic gases to mitigate environmental impact.

Innovations like CONTRAfluran (ZEOZYS, Luckenwalde, Germany) aim to capture 99% of waste anaesthetic gases, intending to recycle them after treatment at dedicated facilities.[43] However, extensive evaluation is necessary before widespread implementation. Addressing propofol disposal is also crucial. Research must determine effective methods to degrade propofol, rendering it environmentally safe before discarding.

Conclusion

In conclusion, anaesthesiologists have the ethical obligation to practice sustainable anaesthesia. Integrating evidence-based sustainability practices within the Malaysian health care system presents an opportunity to reduce the environmental footprint without compromising health care quality or financial stability. Supporting informed procurement, energy efficiency, appropriate waste management, multi-disciplinary collaborative initiatives, and embracing the 6Rs in our daily practice can pave the way for a more sustainable future.

Declarations

Ethics approval and consent to participate:
Not applicable, as this is a review article.

Competing interests
IIS serves as Section Editor for Malaysian Journal of Anaesthesiology. She has 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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Successful utilization of blood purification therapy with Oxiris® haemofilter for the management of severe leptospirosis with multiorgan involvement: a case report

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Abstract

Severe leptospirosis is associated with excessive proinflammatory and anti-inflammatory cytokines that lead to multiorgan failure. Oxiris® haemofilter is a blood purification therapy that can be utilized to control these inflammatory responses during early phase of sepsis-associated acute kidney injury (AKI) that requires renal replacement therapy. We present a case of a 15-year-old male with severe leptospirosis with multiorgan involvement who was admitted to our intensive care unit (ICU). He had septic shock with myocarditis, respiratory failure, AKI with metabolic acidosis, and transaminitis. We started him on continuous veno-venous haemofiltration with the Oxiris haemofilter for metabolic acidosis and cytokine absorption for a total duration of 35 hours. A rapid decrease of vasopressor requirement, lactate, and procalcitonin levels was observed following therapy initiation. He was extubated on day 5 of ICU admission and discharged well to the general ward after 7 days in the ICU. This case highlights the potential benefits of the Oxiris haemofilter

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as an adjunct in the management of septic shock in severe leptospirosis with multiorgan involvement. Randomized clinical trials are warranted to validate the clinical benefits of this therapy.

Keywords: haemofiltration, leptospirosis, Oxiris, septic shock

Introduction

Leptospirosis is a zoonosis caused by pathogenic gram-negative spirochetes of the genus *Leptospira*. In Malaysia, the incidence of leptospirosis is increasing, with national mortality rates between 0.01 to 0.31 per 100,000 population from 2006 to 2015, as reported by the Malaysia Ministry of Health.[1]

A multicentre observational study from central Malaysia has identified lung, liver, and renal dysfunction as well as septic shock as prognostic factors of severe and fatal leptospirosis.[2] At the biochemical level, cytokine markers including tumour necrosis factor (TNF)-α, interleukin (IL)-6, and IL-10 were significantly higher in severe and fatal leptospirosis.[3] Based on this knowledge of the host immune response mechanism during sepsis, extracorporeal blood purification therapy has been proposed as an alternative treatment. Various techniques are available, including high adsorption haemofiltration such as the Oxiris® haemofilter (Baxter, Deerfield, IL, USA). In addition to renal support, this haemofilter removed cytokines, endotoxins, and inflammatory mediators.[4]

Case presentation

A 15-year-old Malay boy with underlying obesity class II presented to our emergency department with a 4-day history of fever, loose stools, vomiting, and reduced oral intake associated with abdominal pain and dry cough. Upon presentation, his blood pressure was 99/30 mmHg, pulse rate was 110 beats per minute, oxygen saturation was 99% under room air, and temperature was 37.8°C. His initial haemoglobin was 12 g/L, white blood cell count was 4.7 x 10^9 L, platelet count was 199 x 10^9 L, with evident of lymphopenia of 1.9%. As he complained of chest pain, a serial electrocardiogram was performed which showed ischemic changes. Troponin I was significantly elevated at 14,215 pg/mL. The diagnosis of leptospirosis was made based on World Health Organization Modified Faine criteria, fever, proteinuria, and epidemiological information from Pahang associated with the rainfall season. The patient had a history of swimming in the river in Kuantan, Pahang.

He was admitted that same day to the intensive care unit (ICU) for septic shock. His arterial blood gas (ABG) showed deterioration of metabolic acidosis with lactate increasing to 4 mmol/L. Hemodynamically, he was started on intravenous infusion (IVI) noradrenaline of 0.5 mcg/kg/min. In the ICU, he was intubated because of acute respiratory failure. Post-intubation, IVI vasopressin was added. He was persistently oliguric, with urine output ranging from 0.3 to 0.5 ml/kg/hr. The patient was diagnosed with septic shock secondary to possible leptospirosis with multiorgan involvement due to myocarditis, respiratory failure, AKI with metabolic acidosis, and transaminitis.

Post-intubation, the patient appeared to have pulmonary haemorrhage based on imaging, blood-stained secretion from his endotracheal tube, shortness of breath, cough, anaemia, and thrombocytopenia. The lowest platelet count was 30

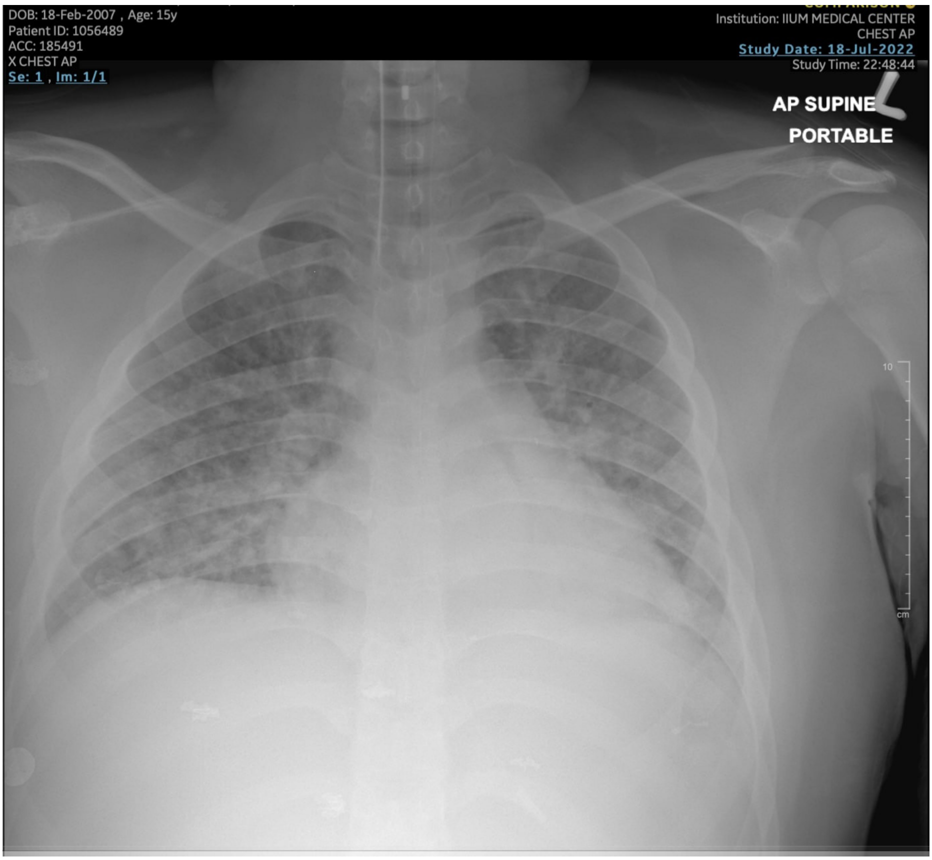

Fig. 1. Anterior-posterior view of chest radiograph post-intubation showing bilateral air space opacification with blunted left costophrenic angle on day 1 of ICU admission.

x 10^9/L. The initial ventilator setting post-intubation was FiO_2 0.6, pressure control was 16 mmHg, pressure support was 12 mmHg, positive end-expiratory pressure was 10 mmHg, and rate was 20 breaths per minute using synchronised intermittent mandatory ventilation mode. His ABG showed pH 7.182, pCO_2 51.9 mmHg, pO_2 104 mmHg, HCO_3- 17.3, BE -8.2, SPO2 96%, and lactate 3.0 mmol/L with a PaO_2: FiO_2 ratio of 173. His chest radiograph post-intubation showed bilateral air space opacification, with blunted left costophrenic angle (Fig. 1). He was empirically treated with intravenous piperacillin-tazobactam and azithromycin for severe leptospirosis and atypical pneumonia.

Continuous veno-venous hemodiafiltration (CVVH) was indicated to treat severe metabolic acidosis and initiate cytokine absorption. On the Prismaflex machine (Baxter, Deerfield, IL, USA), we initiated CVVH with the Oxiris haemofilter as a cytokine absorber at the 7th hour of ICU admission. The Prismaflex flow settings used were blood flow of 200 ml/min, pre-blood pump infusion of 1,000 ml/min, with nil pre-filter replacement flow rate, and 1,000 ml/hr of post-filter. We chose CVVH as the mode of RRT for the purpose of removing low molecular weight proteins as cytokine. After initiation of the Oxiris haemofilter, IVI noradrenaline was gradually reduced and completely stopped on day 3 of ICU admission (Fig. 2a). IVI vasopressin was stopped after 24 hours of ICU admission (Fig. 2a). Notably, the patient's lactate levels reduced significantly after initiation of the Oxiris haemofilter (Fig. 2b).

During the patient's 7-day ICU stay, the Sequential Organ Failure Assessment (SOFA) score decreased by 50%, going from 10 (upon ICU admission) to 5 (upon discharge to the ward). (Fig. 2b). A significant reduction of serum procalcitonin level from 37.6 ng/mL to 6.7 ng/mL (82% clearance) was observed after 35 hours of Oxiris initiation. We discontinued the CVVH after 35 hours due to the marked resolution of septic shock and metabolic acidosis, and recovery of kidney function. His biochemical parameters showed improvement upon discharge from ICU (Table 1). He was extubated on day 5 of the ICU stay and discharged to the ward 2 days following that.

Leptospirosis serology on day 7 of illness confirmed leptospirosis infection. On day 8 of illness, leptospirosis microscopic agglutination test was sent but the result was still pending during the patient's stay in ICU. Although laboratory confirmation of leptospirosis was not available at the time, we treated empirically for leptospirosis based on laboratory parameters. Other than thrombocytopenia, AKI, and elevation of troponin, there was evidence of transaminitis, and hyperbilirubinemia (Table 1). Dengue and malaria investigations were negative.

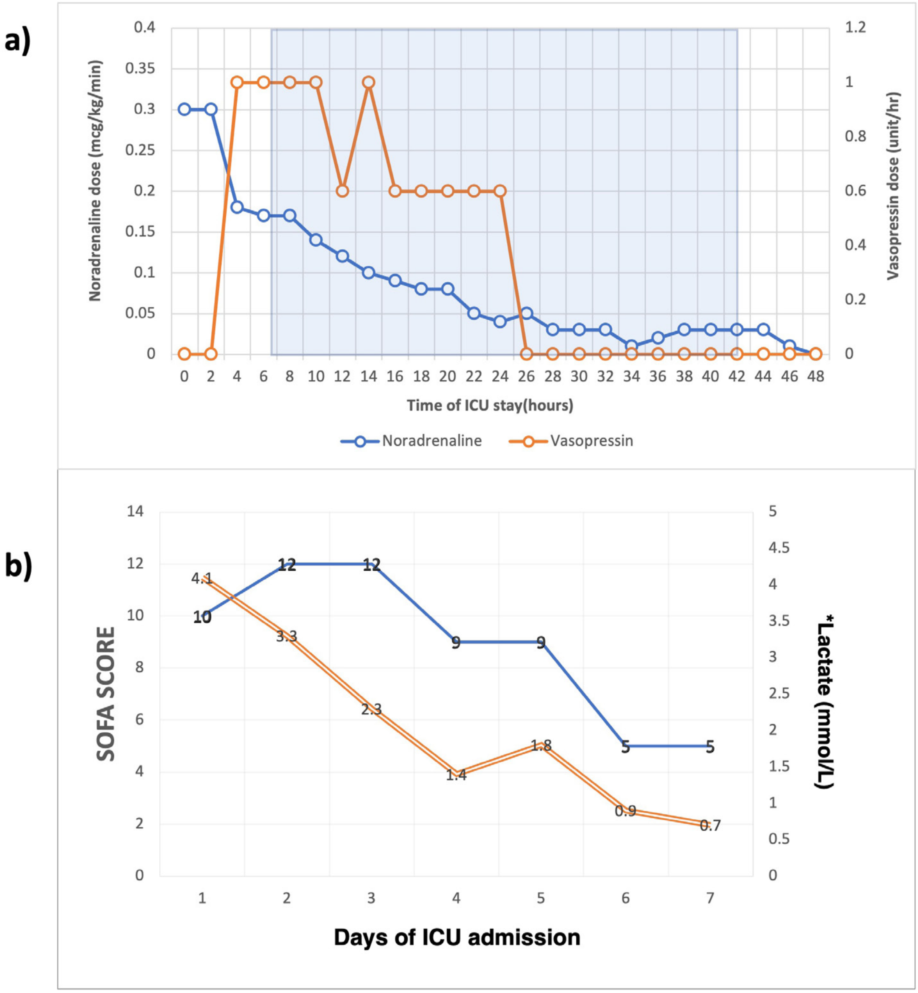

Fig. 2. (*a*) Trend of IVI noradrenaline (µg/kg/min) and IVI vasopressin (unit/hr) dose during CVVH with the Oxiris for a total duration of 35 hours (shaded). After initiation of the Oxiris haemofilter, IVI noradrenaline reduced gradually and was completely ceased on day 3 of ICU admission. IVI vasopressin was off after 24 hours of ICU admission. (*b*) Both SOFA score and lactate levels showed the same reduction trend throughout the ICU stay. The graph shows the highest lactate level from daily ABG.

Table 1. Clinical and laboratory parameters following 35 hours of Oxiris

Blood parameters	*Pre-Oxiris	24 hours post Oxiris	On day of ICU discharge
Full blood count			
Hb, g/dL	8.6	8.6	9.0
TWC, x 10^9/L	21.0	15.8	23.2
Platelets, x 10^9/L	47.0	77.0	271.0
Renal profile			
Urea, mmol/L	16.4	20.8	11.0
Creatinine, µmmol/L	246.0	250.0	111.0
Potassium, mmol/L	3.1	3.6	4.1
Sodium, mmol/L	133.0	140.0	157.0
Urine volume, ml/24hr	895	2690.0	3770.0
Coagulation profile			
PT, s	13.0	10.9	10.6
APTT, s	34.8	26.6	25.9
INR	1.0	0.82	< 0.8
Liver function test			
AST, U/L	120.0	122.0	42.0
ALT, U/L	140.0	196.0	96.0
Bilirubin, µmol/L	85.0	197.0	139.0
Direct, µmol/L	58.5	128.6	73.7
Indirect, µmol/L	26.8	68.4	65.3
Procalcitonin, ng/mL	37.6	6.7	-

*Pre-Oxiris parameters were taken upon ICU admission
Hb: haemoglobin; TWC: total white cell, PT: prothrombin time; APTT: activated partial thromboplastin time; INR: international normalized ratio; AST: aspartate transferase; ALT: alanine transaminase; s: seconds

Discussion

To the best of our knowledge, this is the first report from Malaysia showing the successful use of the Oxiris haemofilter as an adjunct in the treatment of severe leptospirosis with multiorgan involvement. We observed rapid improvement of haemodynamic stability within 72 hours and early reduction of vasopressor dose within the first 12 hours of initiating Oxiris treatment, similar to findings in Europe.[5]

Organ function as reflected by SOFA score during ICU stay improved significantly after initiation of the Oxiris haemofilter. Our patient's highest SOFA score during the ICU stay was 12, which predicted a mortality rate as high as 80%, as reported in a previous prospective study.[6] Despite the high mortality risk, our case has shown successful intervention using CVVH with the Oxiris haemofilter, very possible due to early treatment. Broman *et al* found in their randomised crossover double-blind study that continuous renal replacement therapy (RRT) using Oxiris effectively removed endotoxins such as TNF-α, IL-6, IL-8, and interferon-α during the first 24 hours of treatment in patients with septic shock-associated AKI.[7] Mitigating the "cytokine storm" in the early phase of the illness is beneficial in preventing immunoparalysis where sepsis-associated mortality is observed.[8]

We chose the Oxiris haemofilter blood purification therapy as an adjunct in the management of septic shock with multiorgan failure in our patient for several reasons. The Oxiris haemofilter is comprised of an AN69-based membrane which can adsorb endotoxin and inflammatory mediators from the blood. This is due to the inner aspect of its membrane that is grafted with polyethyleneimine. Its unique feature includes antithrombogenic characteristics owing to its surface being pre-grafted with heparin.[4] However, this feature is a concern for patients allergic to heparin and those with heparin-induced thrombocytopenia.

Our findings may add insights on the use of the relatively new Oxiris haemofilter for RRT and multiorgan support in patients with septic shock. We believe that our patient benefited from Oxiris treatment, as its membrane filter endotoxins, which are the key component of sepsis due to gram-negative bacteria in leptospirosis. Shum *et al.* reported significant reduction of the SOFA score in 6 patients with sepsis-induced AKI due to gram-negative bacteria within the Oxiris group in comparison to the control group.[9] However, early antibiotic initiation and the young age of our patient could also be contributing factors of the marked improvement in his clinical outcomes.

The usage of Oxiris is convenient as we are familiar with conventional CVVH in our daily practice. No adverse events were observed during the treatment. However, this is a case report of a single patient, and randomized controlled trials are needed to demonstrate its benefit in clinical practice. This is consistent with the 2021 update of Surviving Sepsis Campaign that to date, no recommendation has been made regarding the use of Oxiris.[10] A limitation of our study is that we were unable to measure the concentration of inflammatory mediators such as IL-6 and IL-10 pre- and post-initiation of Oxiris to establish a direct causal relationship.

Conclusion

Although routine usage of the Oxiris haemofilter is challenging due to its cost, its application should be explored further as it has the potential to increase survival rate and reduce morbidity in septic shock, including those from severe leptospirosis as demonstrated in our case report. Larger clinical studies are needed to establish patient selection, efficacy, and timing for initiation of blood purification therapy with the Oxiris haemofilter.

Declarations

Informed consent for publication

The authors obtained written informed consent from the patient and their next-of-kin for the publication of the images and clinical data contained in this case report.

Competing interests

Dr. Azrina Binti Md Ralib serves as Deputy Chief Editor in Malaysian Journal of Anaesthesiology. She has 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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Use of dexmedetomidine and low-dose ketamine as conscious sedation for fibreoptic bronchoscopy intubation for temporomandibular joint ankylosis secondary to an unsuspecting childhood trauma: a case report

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Abstract

Airway management in the paediatric population is known to be challenging due to its unique anatomical and physiological differences. Maxillofacial injuries further complicate airway management. To date, there is limited evidence to support the technique of airway management and the choice of drugs used in the paediatric population. This case report aims to describe the technique of conscious sedation using dexmedetomidine and ketamine to perform an awake fibreoptic intubation in the case of an 8-year-old boy with limited mouth opening due to a temporomandibular joint ankylosis secondary to childhood trauma. The endpoint of this case report showed that this technique proved effective with a good margin of safety in this paediatric patient with an airway concern. Further studies are needed to validate this observation.

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Keywords: dexmedetomidine, fibreoptic intubation, oromaxillofacial surgery, paediatric anaesthesia, temporomandibular joint ankylosis

Introduction

Airway management of paediatric patients is known to be challenging due to its unique anatomical and physiological differences.[1] Additionally, maxillofacial injuries can complicate the airway further and the surgery itself may often preclude the use of an oral route for intubation.[2] Fibreoptic bronchoscopy intubation remains the gold standard for an anticipated difficult airway.[3] However, it is difficult to get full cooperation from paediatric patients to perform an awake fibreoptic intubation.[4] There is limited evidence to support the superiority of the choice of drugs in the paediatric population.[5] In this case report, we describe a successful nasal fibreoptic intubation of a child with limited mouth opening due to a temporomandibular joint ankylosis secondary to childhood trauma with conscious sedation by using the combination of ketamine and dexmedetomidine.

Case report

An 8-year-old boy, with normal growth (weight 18.4 kg) was referred to the dental team for limited mouth opening causing reduced food intake. Upon further history, the child had a history of fall when he was 1 year old and was noted to have facial asymmetry when he was 2 years old. However, no medical attention was sought as the patient did not complain of pain or swelling. On physical examination, there was an obvious facial asymmetry with retrognathic mandible more prominent on the right side with a midline shift to the left upon mouth opening. The inter-incisor distance was only 1 finger breath space. Due to the limited mouth opening, the child presented with multiple dental caries with mixed dentition. Otherwise, the mother denied any obstructive sleep apnoea symptoms or snoring noted during sleep, and the child appeared active during daytime.

The oral and maxillofacial surgery (OMFS) team decided for a 2-stage surgery to correct this deformity. The first stage of surgery was distraction osteogenesis of the mandible followed by a total excision of the ankylotic mass over left condyle via extraoral approach, left cornoidectomy, lining of glenoid fossa region with temporalis fascia and fat graft.

Fig. 1. Preoperative evaluation of the patient's airway showing very limited mouth opening with a narrow chin from temporomandibular ankylosis.

Fig. 2. (*Left*) Topicalization of upper airway with nebulized lignocaine with adrenaline 1:10,000. (*Center*) Nasopharyngeal airway inserted into the right nostril to maintain ventilation and oxygenation. (*Right*) Introduction of fibreoptic bronchoscope into the left nostril without struggle.

During the preoperative review (Fig. 1) in our unit's anaesthesia preoperative clinic, the nasal route of fibreoptic intubation and possible surgical airway was discussed with the mother as the most viable option after all the risks and benefits were explained.

On the day of surgery, the child was accompanied by the mother to the operation theatre. Standard monitoring, electrocardiogram, non-invasive blood pressure monitoring, and SpO_2 monitoring were applied. Intravenous glycopyrrolate 5 mcg/kg was administered as an antisialogue. Nebulized lignocaine (preservative free) 2% with a mixture of adrenaline 1:10,000 (dilution: 40 mg of lignocaine (2 ml 2%, 2.5 mg/kg) + 0.1 mg of adrenaline (1 ml of 1:10,000 adrenaline)) was administered over 5 minutes (Fig. 2). While the topicalization of the airway was ongoing, an infusion of dexmedetomidine was already initiated with the endpoint of titration guided clinically by the patient's heart rate, blood pressure, respiratory rate, and consciousness level: this was done very gently with a starting dose of 0.5 mcg/kg/hour and gradually increased by 0.2 mcg/kg/hour until 1 mcg/kg/hour, as to reduce the incidence of profound bradycardia which may develop in children if given at 1 mcg/kg/hour over 10 minutes in the beginning. The child was transferred to the operating table once he was lightly sedated and calm.

The plan was to insert nasopharyngeal airway via the left nostril for oxygen delivery and the right nostril to insert a fibreoptic scope. As the nasopharyngeal airway (size 5) was being inserted in the left nostril with the circuit connected and the endotracheal tube was mounted before the introduction of a fibreoptic scope, the child exhibited mild agitation and resisted the procedure. Consequently, a dosage of intravenous ketamine at 1 mg/kg was administered for its rapid drug onset with a background infusion of dexmedetomidine of 1 mcg/kg/hour. The procedure was then followed by the insertion of fibreoptic bronchoscope (11301AA1 OD 2.8 mm, Karl Storz, Germany) into the right nostril with the endotracheal tube (size 4.5) loaded to the shaft of the scope (Fig. 2). Upon visualization of epiglottis and vocal cord, 2 ml lignocaine 2% was instilled via the side port of the fibreoptic scope, was advanced into the trachea (above the carina), and the cuffed endotracheal tube was railroaded along the fibreoptic scope. Placement of the endotracheal tube was confirmed by capnography tracing and direct visualization of the fibreoptic scope.

Once the airway was established, intravenous propofol 1 mg/kg was administered and maintained with inhalational sevoflurane and a background infusion of dexmedetomidine of 0.3 mcg/kg/hour without muscle relaxants. There were no episodes of desaturations/apnoea and the child remained haemodynamically stable during the handling of airway. The total duration of surgery lasted for approximately 4 hours with minimal blood loss. Postoperatively, the patient was planned for delayed extubation in the Paediatric Intensive Care Unit with infusion of dexmedetomidine. The child was subsequently extubated on the following day with no immediate complications observed. The child remained well and was transferred to the ward for daily distraction of the mandible. The child had no recall of the process of intubation.

Discussion

Limited mouth opening is common among patients with temporomandibular ankyloses. The initial plan of laryngoscopy or the use of supraglottic airway as a conduit were not possible; hence, the nasal route of intubation or tracheostomy was the remaining option. With the advancement of our airway equipment, surgical airway is no longer routinely practiced.[6] A similar case from Sharma *et al.*[7] described asleep fibreoptic intubation with an incremental dose of sevoflurane and maintenance of spontaneous breathing in a child with limited mouth opening for temporomandibular joint ankylosis.

In our case, nasal mucosal anaesthesia was achieved with nebulized lignocaine 2% + adrenaline 1:10,000 (1 ml, 0.1 mg) simultaneously with initiating infusion of dexmedetomidine. The safe dose for nebulized lignocaine (without adrenaline) varies from 4–8 mg/kg.[8] In this patient, the total dose of lignocaine was only 2.5 mg/kg with the addition of adrenaline 1:10,000 (1 ml, 0.1 mg), which is far from the suggested toxic dose dosage. Nevertheless, we did not observe significant efficacy in anesthesia of the nasal mucosa through nebulized lignocaine as the child exhibited resistance during the initial insertion of a nasopharyngeal airway while receiving the dexmedetomidine infusion. As a result, intravenous administration of ketamine was required to expedite the onset of anesthesia and ensure patient comfort. Dexmedetomidine was chosen for conscious sedation due to its anxiolytic effect, lower respiratory compromise, and mild analgesic properties.[9] However, the evidence is limited thus far.[10]

It is almost impossible to perform awake fibreoptic bronchoscopy intubation in the paediatric population. Even employing the conscious sedation technique, this needs to be performed by skilled personnel to increase the first pass success rate. Inhalational agents were not used in this case, as we wanted to ensure the child was adequately sedated via intravenous sedatives. Alternatively, total intravenous anaesthesia (TIVA) with propofol with/without remifentanil has also been described as one of the techniques commonly used in managing awake fibreoptics intubation.[3] The use TIVA with propofol with/without remifentanil was not chosen for our patient due to concerns about apnoea during drug titration and the need to maintain spontaneous respiration. Additionally, the patient's temporomandibular deformity excluded the use of supraglottic airway, which could potentially lead to airway obstruction. Both dexmedetomidine and ketamine allow maintaining the patient's spontaneous respiratory effort and provide a relatively safe haemodynamic profile.[11] Dexmedetomidine has also exhibited additional potential for utilization in the perioperative phase, specifically due to its favourable impact on surgical stress response, as an adjunct for pain relief and possibly as a preventive measure against postoperative delirium and agitation, which was crucial in this case to ensure maximal cooperation of the patient during the postoperative period in the intensive care unit.[12]

However, the selection of drugs ultimately relies on the familiarity and availability of local hospital policies and experiences. In cases where resources are limited (such as a lack of dexmedetomidine or unfamiliarity with its usage), we recommend alternative drug options that can maintain spontaneous respiration while ensuring sufficient sedation levels. For instance, TIVA propofol with/without remifentanil could be considered provided adequate topicalization of the airway is performed to ensure a smooth induction process. Appropriate case selection is also another factor for this successful intubation. The child was cooperative and was not agitated. Rapport with the patient was built to gain maximum trust. If the child is not cooperative, the asleep technique would have been better than conscious sedation.[7]

A limitation presented by this case was that full cooperation from a pediatric patient may not be possible to allow awake fibreoptic bronchoscopy intubation, even though this is the gold standard to secure the airway in an anticipated difficult airway case. Another limitation was that nostril topicalization with packed cocaine was also not feasible; therefore, nebulized lignocaine with adrenaline was used.

Conclusion

Fibreoptic bronchoscopy intubation remains an essential skill yet carries a challenging learning curve for anaesthetists dealing with an anticipated difficult airway in the paediatric population. Ketamine and dexmedetomidine were chosen as the anaesthetic agents in this case as these drugs allow spontaneous breathing and have a good safety margin. Further studies are needed to validate this observation.

Declarations

Informed consent for publication

Written informed consent was obtained from the patient’s parent for the publication of the clinical data and images contained in this case report.

Competing interests

None to declare.

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Gastric ultrasound for perioperative prandial status

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Abstract

Gastric ultrasound is a valuable tool for real-time assessment of gastric content at the bedside, reducing the risk of pulmonary aspiration. A good understanding of the gastric sonoanatomy and techniques for image acquisition will allow the clinician to utilize ultrasound to assess gastric content and volume via qualitative and quantitative assessment to risk stratify their patient prior to the surgery. We describe the core principles of gastric ultrasound and its practical implications on patient safety during the perioperative period.

Keywords: gastric ultrasound, perioperative ultrasound, point-of-care ultrasound, risk stratification, pulmonary aspiration

Introduction

The use of perioperative ultrasound by anaesthesiologists has significantly increased in recent years. Initially, it was primarily utilized by cardiovascular anaesthesiologists for transoesophageal echocardiography. Its application has expanded to include ultrasound-guided regional anaesthesia and vascular access.[1] Gastric ultrasound has particularly captured the attention of anaesthesiologists as a valuable tool for real-time assessment of gastric volume at the bedside, reducing the risk of pulmonary aspiration.[2,3] This brief communication describes the core

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principles of gastric ultrasound and its practical implications on patient safety during the perioperative period

Basic principles of gastric ultrasound assessment

Gross anatomy of the stomach

There are three main regions in the stomach: the cardia, fundus, and pylorus (Fig. 1).

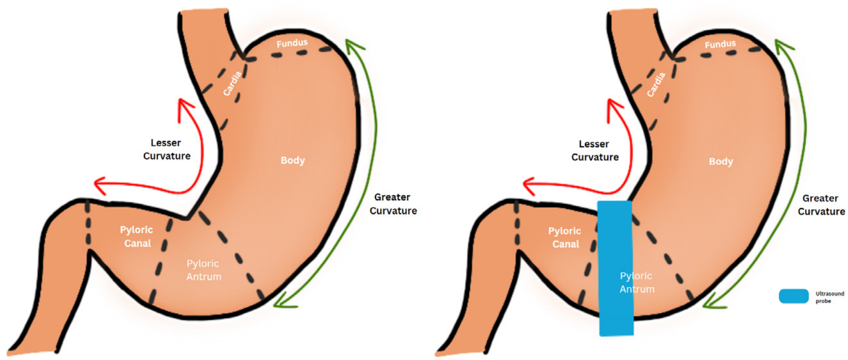


Fig. 1. The gross anatomy of the stomach and its main region (left); blue rectangle box indicating the structure that is visualized by the ultrasound (right).

Indications

Patients with uncertain prandial status, and known or suspected delayed gastric emptying.

Probe selection

Low-frequency curved array transducer (1-5 Mhz); high frequency probe can be used in leaner/paediatric population.

Position of patient

Supine and right lateral decubitus position (Figs. 2 and 3); semirecumbent is an alternative if unable to turn lateral.

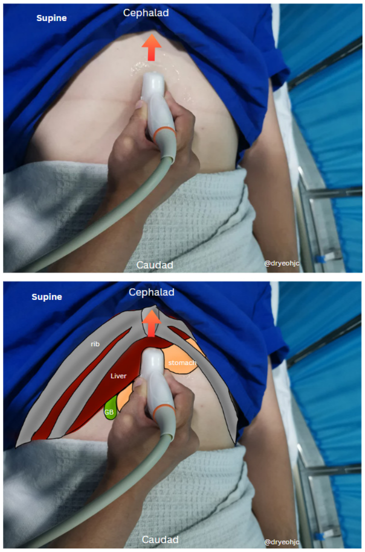


Fig. 2. Probe position at the epigastrium region in a supine position.[4]

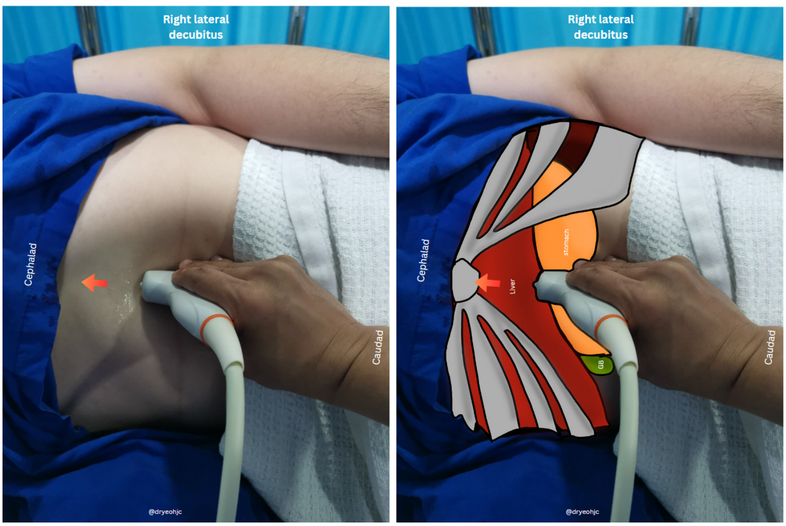


Fig. 3. Probe position at the epigastrium region in a right lateral decubitus position.

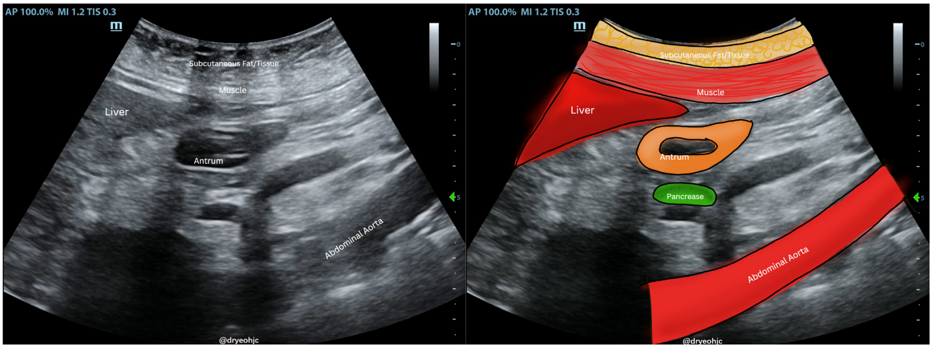


Fig. 4. Sonoanatomy to be identified during gastric ultrasound.

Transducer position

In the sagittal plane at the epigastrium region, perpendicular to the skin (Figs. 2 and 3). Tilt/slide/rotate the probe to best obtain a true cross-sectional view of the antrum (the smallest possible cross-sectional view for the measurement of the gastric volume).[3]

Anatomy to identify

A portion of the liver, long axis of the abdominal aorta or sometimes the inferior vena cava, pancreas (posterior to the antrum), and short axis of gastric antrum (easiest to obtain) as per Figure 4.

Qualitative assessment with gastric ultrasound (Table 1 and 2)

Table 1. Qualitative/visual assessment[2]

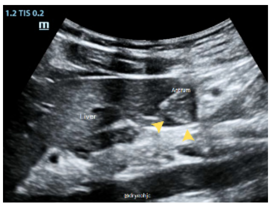
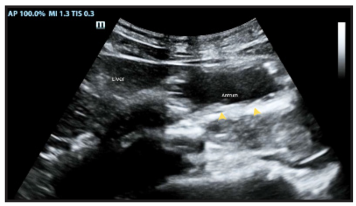
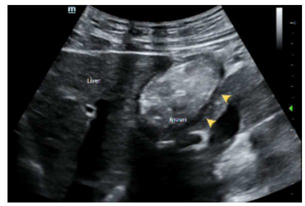
	Empty	Clear fluid	Milk or suspensions	Solid
Antral	Flat, collapsed, or circular (resembling a bull's eye)	Circular, well filled lumen	Circular, well filled lumen	Circular, well filled lumen
Antral wall	Thick wall with prominent muscularis propriae	Thin wall	Thin wall	Thin wall
Content	None Grade 0, or small	Hypoechoic	Hyperechoic	Hyperechoic, heterogenous (mixture with air in gastric)
Peristalsis	No peristaltic movement	Present	Present	Present
Ultrasound anatomy	 [Figure A] Sonographic image of an empty stomach. Note the antrum is collapsed with no visible content	 [Figure B] Sonographic image of the gastric antrum with hypoechoic/anechoic content.		 [Figure C] Sonographic image of gastric antrum with solid content

Table 2. Grading score for gastric content

Grade	Features
Grade 0	The antrum appeared **flattened and empty** in both supine and right lateral decubitus position
Grade 1	Fluid can be demonstrated in the antrum **only** in the right lateral position
Grade 2	Fluid or fluid is demonstrated in the antrum **in both** supine and right lateral positions

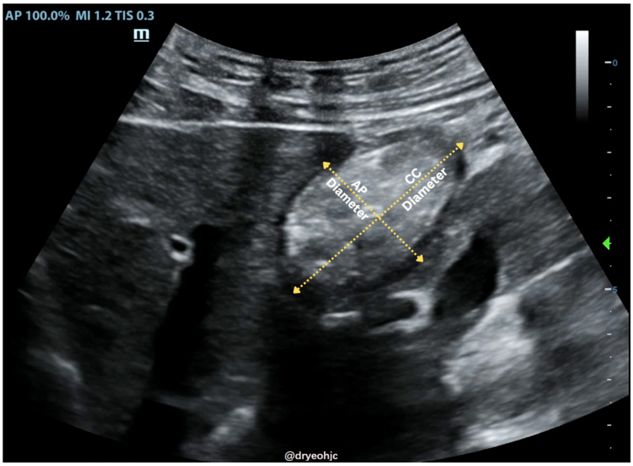


Fig. 5. Anterior-posterior (AP) diameter and cranio-caudal (CC) diameter is required for cross-sectional area (CSA) measurement.

Quantitative assessment with gastric ultrasound

Figure 5 shows the application of Perlas formula (widely adopted, simplified).[5]

- Gastric volume (ml) = 27.0+ [14.6 × CSA $^{\text{right-lateral}}$ (cm^2)] – [1.28 × age (years)]
- CSA measurement: (π x CC X AP) / 4, serosa to serosa wall (Fig. 5).

Risk stratification by gastric volume (Table 3)

Figure 6 shows the proposed clinical algorithm for gastric ultrasound and aspiration risk assessment via qualitative and quantitative measures.

Table 3. Risk stratification by gastric volume

Gastric volume (ml/kg)	Risk stratification
<1.5 ml/kg	Low risk
>1.5 ml/kg	High risk

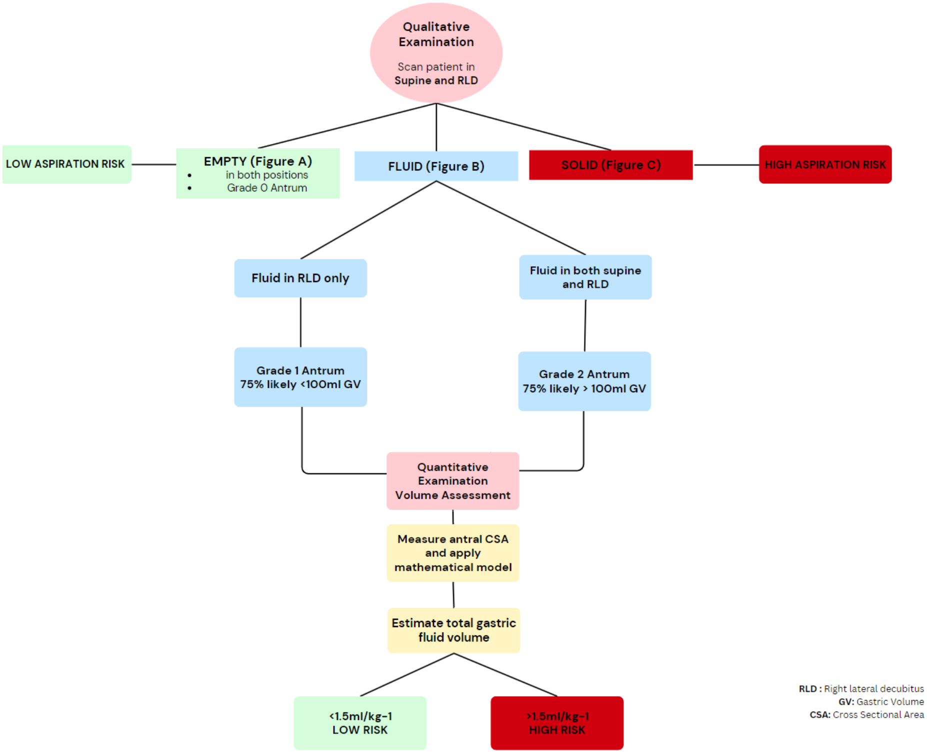


Fig. 6. Proposed clinical algorithm for risk stratification for pulmonary aspiration. Adapted from Van de Putte and Perlas.2 CSA: cross-sectional area; GV: gastric volume; RLD: right lateral decubitus

Clinical applications of gastric ultrasonography

Fasting for emergency surgery does not ensure an empty stomach.[6] Gastric ultrasound can serve as a useful tool alongside standard practices to enhance safety during anaesthesia with high levels of sensitivity (1.0), specificity (0.975), positive predictive value (0.976), and negative predictive value (1.0) when there is uncertainty about the fasting status.[7] When considering factors such as surgical urgency, medical conditions, and alternative anaesthetic techniques, gastric ultrasound has been shown to influence anaesthetic approaches significantly. With precise sonographic findings, anaesthesiologists are able to make informed decisions regarding surgery scheduling and anaesthesia management. They can choose to postpone or cancel a procedure if necessary, or proceed with the appropriate technique.[8] This may involve employing rapid-sequence induction, tracheal intubation, or regional anaesthesia.[3,8]

Conclusion

Gastric ultrasound assessment is an essential tool to determine prandial status in the perioperative period. The findings can be used to guide the decisions regarding scheduling and anaesthetic technique.

Declarations

Ethics approval and consent to participate
Not required, as this is a literature review.

Competing interests
Dr. Shahridan Mohd Fathil serves as Deputy Chief Editor for Malaysian Journal of Anaesthesiology. He has 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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