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NARRATIVE REVIEW

A way forward in pulmonary aspiration incidence reduction: ultrasound, mathematics, and worldwide data collection

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Abstract Aspiration of gastric contents during induction of general anesthesia remains a significant cause of mortality and morbidity in anesthesia. Recent data show that pulmonary aspiration still accounts for many cases with implications on mortality despite technical and technological evolution. Practical, ethical, and methodological issues prevent high-quality research in the setting of aspiration and rapid sequence induction/intubation, and significant controversy is ongoing. Patients' position, drugs choice, dosing and timing, use of cricoid force, and a reliable risk assessment are widely debated with significant questions still unanswered. We focus our discussion on three approaches to promote a better understanding of rapid sequence induction/intubation and airway management decision-making. Firstly, we review how we can use qualitative and quantitative assessment of fasting status and gastric content with the point-of-care ultrasound as an integral part of preoperative evaluation and planning. Secondly, we propose using imaging-based mathematical models to study different patient positions and aspiration mechanisms, including identifying aspiration triggers. Thirdly, we promote the development of a global data collection system aiming to obtain precise epidemiological data. Therefore, we fill the gap between evidence-based medicine and experts' opinion through easily accessible and diffused computer-based databases. A better understanding of aspiration epidemiology obtained through focused global data gathering systems, the widespread use of ultrasound-based prandial status evaluation, and development of advanced mathematical models might potentially guide safer airway management decision making in the 21st century.

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Introduction

Soon after Mendelson described aspiration pneumonia, a study of 1,000 anesthesia-related deaths revealed regurgitation and vomiting as the leading cause of death due to anaesthesia.[1] In the 1960s, anesthesiologists developed improved airway management techniques, including cricoid force and rapid sequence induction/intubation (RSI) for high-risk patients. Since then, there has been a decline in pulmonary aspiration incidence.[2,3] More recently, data from the UK National Audit Project 4 showed that aspiration remains the single most common cause of death related to airway management, where for 34 reported cases, 11 resulted in death or brain damage.[4]

With its reported incidence of 2–7 per 20,000 anesthetic cases, each anesthetist should experience 4–14 pulmonary aspiration events in their career, depending on the area of work and number of emergency cases.[4,5] In emergency surgery, this complication's incidence increases to 0.5%, provided that anesthetic induction occurs in the operating room's controlled environment.[2] There is a further increase to 2.7% for in-hospital emergency cases outside the operating room.[6] We believe that the following three approaches should lead to a further decrease in pulmonary aspiration incidence in the 21st century: ultrasound, mathematics, and global data collection.

Pulmonary aspiration risk assessment: is ultrasound the answer to our prayers?

For each anesthesia case, examination includes an aspiration risk assessment. If compliant with the official fasting times,[7,8] the elective and ''healthy'' surgery patients usually have an uneventful anesthesia, but what about those with concomitant risk factors for pulmonary aspiration? Moreover, what about the significant proportion (up to 35%) of fasted patients, who have a full stomach on gastric ultrasound, despite fasting for a minimum of 6 hours (median of 16 h)?[9] How many of risk factors are needed, and what is their relative weight in a particular patient?

New antidiabetics can add another coefficient to the pulmonary risk assessment equation: GLP-1 receptor agonists like exenatide or liraglutide increase glucose-stimulated insulin secretion, suppress glucagon, and slow gastric emptying.[10] While gastroparesis is already a feature of advanced Diabetes Mellitus, these agents may slow gastric emptying further.[11] Therefore, it seems reasonable to expect an increased risk of aspiration with the use of these agents, particularly in diabetic patients with known peripheral neuropathy and gastroparesis.

Point-of-care ultrasound might be a potential solution to this conundrum. With gastric ultrasound (GUS), we can determine the patients' gastric content in at least 85% of obstetric, 90% pediatric, and 95% of other patients.[12,13] Despite some limitations of GUS, the first being operator dependency,[12] it represents one of the most objective tools for routine aspiration risk assessment for many semi-emergency patients. With GUS we can assess the aspiration risk better than ever before, not underestimating the opportunity to expand our airway examination and assessment[14] to tailor the anesthetic plan and provide safer and more optimal anesthesia care.

If the stomach is empty, we should be able to proceed safely with any airway management approach. However, one should use the correct patient position for scanning: 45° head up right lateral position. In obstetric patients, this position was superior to supine 45° head-up position, as 60% of images that indicated an empty antrum turned out to be incorrect in the right lateral position.[12] If adequate positioning is not possible, the ultrasound interpretation is no longer reliable. We should be aware of such potential false-negative examinations. Thus, appropriate patient positioning is imperative.

If there is food in the stomach, then surgery should be postponed, if feasible. Currently, interpretation of the presence of liquid in the stomach is the most difficult. The proposed cut-off was set at 1.5 mg kg^{-1}, although it is also hard to ascertain which volume poses an increased risk.[15] All in all, gastric ultrasound might also lead to safer pediatric anesthesia, as its use increases the 50:50 chance of correct clinical decision-making to an 85% correct choice of the appropriate induction technique.[13]

However, the major limitation remains that the gastric content's ultrasound findings do not directly correlate with pulmonary aspiration,[12] and studies addressing this issue would be ethically questionable to perform. Additionally, only circa 10% of anesthesiologists globally are currently trained in GUS.[16]

Patient positioning for the RSI: the Holy Grail of controversies?

Secondly, we would like to emphasize an area of RSI controversy that needs to be addressed by advanced mathematical modelling: patient positioning during RSI. Three leading patient positions are generally considered: head up (reverse Trendelenburg); horizontal-supine, and head down (Trendelenburg). The first position advocates many benefits, including better preoxygenation conditions, better intubation conditions, and less chance of regurgitation. However, if/when regurgitation occurs, then material empties into the lungs by gravity. One of the treatments, in this case, is to turn the patient head down,[3,17] which in a controlled setting would require at least 20 seconds (depending on the technical characteristics of the operating table and human factors). Those who prefer the head down position need to acknowledge the worse intubation conditions, worse preoxygenation (unless the patient is first preoxygenated in head-up position and then turned head down anesthetic induction), and a higher chance of regurgitation. But if regurgitation occurs, the material empties of the mouth and the nose. Studies show that the head-down position does not alter the pressure in the lower esophageal sphincter tone, hence questioning whether this position would increase the likelihood of regurgitation.[18]

At present, there is no good evidence in support of either position, except for expert opinion or in specific populations – such as obese patients – where advantages of the head-up position seem to overweight the risks and benefits of alternative positions.[19] We need to ascertain whether these assumptions are correct, as well as investigating the conditions under which the gastric contents would enter the lungs in the head-down position. Some steps in this direction have been taken, when a group used the simulation manikin to establish the times to intubation and the volume of aspiration in different patient positions.[20] It would also be clinically interesting to determine how much time passes from when the gastric contents' entrance into the esophagus until aspiration, for different patient positions. We suggest building a clinically relevant computer-tomography derived anatomical model and developing numerical mathematical modelling of aspiration. By being based on anatomical data from a variety of patients, such a model could also test the boundary/trigger conditions needed for pulmonary aspiration to occur, i.e., the volume and nature of gastric contents, the pressure gradients, etc. A similar model could also be used to assess the still largely debated application of cricoid force during RSI with consistent cost-benefit analysis, ideally with cadaveric and live animal validation experiments.

Global database reporting system: evidence gathering solution?

The third action to further decrease pulmonary aspiration incidence is the establishment of a global data reporting system. Through a webpage and a mobile device application, an anonymous collection of aspiration events can guide reports and focus on ongoing controversies. This way, we might obtain the relevant data in a few years, as the annual worldwide incidence of pulmonary aspiration is in the order of thousands. By examining the data from 2012, when the annual number of surgeries delivered worldwide was estimated as 313 million, we can calculate the annual global incidence of pulmonary aspiration at least 110,000 cases.[21] The number is probably even higher now, as the frequency of surgical procedures and anesthesia care has again increased over the last 8 years. The ability to gather and analyze hundreds or possibly thousands of pulmonary aspiration cases globally could lead to better-informed practice and evidence-based data, instead of mainly relying on expert opinion. This approach may be a potential strategy to prevent and minimize airway management complications.[22]

The results of a recent worldwide survey on RSI with more than 10,000 respondents[16] showed a huge variability in RSI practice. For example, cricoid force would be used in 71% during RSI for a hypothetical patient with intestinal obstruction and only 50% for any other patient undergoing RSI. This conflicts with deliberate practice principles which ought to be followed in order to achieve and maintain expert performance in RSI. A strong association of cricoid force use with decreasing national income could also be ascertained. Important variability was also found for patient positioning and nasogastric tube use. Such databases allow comparison with previously published data and can balance the discussion to the best available evidence, while determining what happens at the bedside.

As the volume of data continues to grow, its potential for elucidating this decade-long discussion seems to be growing. In critical decisional setting, we have growing evidence that many accidents occur because of human factors, including fixation errors and lack of effective communication. Therefore, we believe that gathering data assumes the other meaning of becoming a way to discuss our errors and to learn from them (promoting the no-blame culture) and to introduce not only technical but also non-technical aids to improve practice and patient safety.[23,24]

Conclusions

For decades, many different techniques have been investigated to decrease the incidence of pulmonary aspiration. Despite much research, many controversies regarding RSI exist. The three measures discussed (gastric ultrasound for pulmonary aspiration risk assessment, mathematical modelling, and global data collection through the exploitation of available social networking platforms) may aid us in improving the safety of airway management decision-making in the near future.

Conflict of interest

The authors declare no conflicts of interest.

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