Review article

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THE ROLE OF ULTRASOUNDS IN PLANNING AND DEVELOPING AIRWAY MANAGEMENT STRATEGIES

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Ultrasounds represent one of great innovations in the field of medicine in the last century; thanks to technological development, instrumentation design and portability, they became widespread used in many fields of medicine, including anesthesia. Apart for consolidated role for central venous lines placement and for regional anesthesia, where they succeeded to reduce complication rate while increasing performance, they are now more and more frequently used also for airway management, for different purposes. They are powerful tools for second level airway assessment, with reference to evaluation of anatomy and difficult airway management prediction; they are also used for tube position confirmation (especially in the field of emergency), for cricothyroideal membrane identification, for evaluation of glottic diameter prior to extubation, for airway devices position evaluation (such as LMA), for tube size choice (especially in pediatric patients), for preprocedural evaluation during tracheostomy and for endobronchial diagnosis of lung pathology.

Principal applications of ultrasounds in airway management, including literature analysis and identification of evidence based indications are discussed.

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Key words: *ultrasounds, airway management, intubation, tracheostomy, cricothyrotomy*

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Introduction

Due to technological development, diagnostic and interventional ultrasounds (US) have a crucial role in many areas of medicine, and thanks to devices miniaturization and portability, they are more and more used also by non- Radiologists, such as Anesthesiologists.

In 1999 Hatfield and Bodenham predictively affirmed that ultrasounds could represent "a developing area which is likely to expand rapidly when clinicians appreciate the true potential of such technique" (1), but for sure it was out of their imagination that less than 15 years later, US technology would have been so represented in Anesthesiologists' hands. Central and peripheral lines, arterial lines, peripheral and central blocks, FAST protocols for emergency abdominal exploration, lungs echo exploration and fast echocardiography represents only some of the common and widespread applications of US in Emergency Department, Anesthesia and Intensive Care.

In the last years, thanks to the above mentioned technical development, the use of US for airway management has gained a certain success and diffusion, representing an attractive and pluripotential field of application for this easy, safe, low cost and low skill (at least for basic use) technology.

The first ultrasound instrument was introduced in the early 1950s, but it was only in the 1960s that similar units became available for limited, primarily experimental use. In the early 1980s, there had been significant improvement in the technology to the extent that real-time ultrasound was developed, and real-time scanning was one of the most significant factors conditioning applications and large use of US (2). The American College of Emergency Physicians (ACEP) offered its first course specifically dedicated to emergency applications of ultrasound in 1990, and in 2001, ACEP published the Emergency Ultrasound Guidelines, which pertain to the scope of practice and clinical indications for emergency ultrasonography (3). Nevertheless, despite such earliest reports dealing with US applications in clinical medicine include the description of soft-tissue imaging of the pretracheal structures and anterior tracheal wall (4), the first detailed reports of using US to assist in various applications in airway management date from only a few years ago, that is why this peculiar field of US application is still to be well studied and established, and it probably represents the future for development of such a technique (5).

Technical aspects of US for airway management

Further readings are available to better understand principles of US (6), and also to consider recently published papers which might higlight potential biological US side effects (7). Specific probes are required for airway study, such as Linear 7 - 12 MHz and Convex 2 - 6 MHz probes (8); for this reason, typically, vascular-type probes with high frequencies (> 7.5 MHz) and high resolution are used (9). The main concern for use of US in the airway is represented by US reflectance attissue-air interface (and air is the most represented element inside normal airways), as because of an-echoicity of air. So, due to what is called the very high acoustic impedence of air, US cannot directly depict the inside of any air-filled organ: as a result, despite a very good view of larynx, trachea, epiglottis, cricoid cartilage, which are clearly echoic, a limited view can be obtained for whatever is in the background. As a result, while we can easily have a good view, due to their superficial position, of the frontal and lateral walls of nearly all upper airway segments, the cuff of an endotracheal tube is hardly detected, if not inflated with fluid (US reflective) (1). Airway "sonoanatomy" regards different structures: US can image the floor of the oral cavity and its lateral wall with vertical and diagonal scansions; the lateral walls of the nasal cavity are only rarely visible (only if if the maxillary sinuses are filled with liquid), while the larynx could be seen as a musculocartilaginous structure situated below the hyoid bone which remains very clearly visible by US as hyperechoic structure (cartilage) reciprocally connected by isoechoic membranaceous ligaments with visible air below. US could also be used to explore vocal cords, which could only be examined by preoperative endoscopy (10), and they could also be powerful instrument to assess and provide follow up of postoperative vocal cords dysfunctions (11). Tracheal rings, down from the cricoid cartilage, are easily visible by US in vertical or transversal section together with the differently echoic pretracheal tissue.

Applications of US for airway assessment

US approach might represent a low cost/low skill and noninvasive test for routine second level study of the airway: as an operative strategy we could suggest using US in all cases where some suspects arise after an inspective clinical study of the patient. A recent study compares clinical and ultrasonographic airway examination (12), concluding that upper airway US is capable of providing detailed anatomic information and has numerous potential clinical applications. An interesting paper by Sustic (9) underlines a number of attractive advantages for US compared with competing imaging techniques or endoscopy, starting from advantage that US are widely available, portable, repeatable, relatively inexpensive, pain-free, and safe.

Ezri and Coworkers (13) higkighted the role of obesity as independent predictor of difficult intubation with an elegant US-based study, providing a neck thickness/circumference cut-off value and confirming that US better than increased body mass index per se could predict difficult laryngoscopy. On this pathway, US have been used for diagnosis of airway masses, anatomical deformities (1, 8, 14) and last but not least for Obstructive Sleep Apnoea Syndrome (OSAS) diagnosis and consequential airway management implications (8, 15). The use of US still remains open questions an isolated tool for predicting difficult laryngoscopy, but on the other hand it could easily be second line instrument to perform more accurate predictions (16).

US could also be used to preoperatively assess diameter of endotracheal tube to be used, which could be of particular interest in children due to their different airway anatomy; different papers have been published with no homogeneous results, indicating not high predictive value but starting from point that same formulas used for tube diameter prediction result poorly effective (17).

Applications of US for airway management: ET tube position

According to worldwide airway management guidelines, (18),insertion of an endotracheal tube must be followed by mandatory position confirmation test to exclude inadvertent or unrecognized esophageal or endobronchial intubation; due to poor effectiveness of simple chest auscultation (though bilateral and extended), exhaled CO2 detection or direct fiberoptic view through the endotracheal tube universally remain the gold standard techniques for correct intubation confirmation. From this point of view, US, despite the afrementioned technical limitations for direct detection of tracheal tube cuff, might represent a simple and low cost alternative, especially in some settings such as out of hospital emergency, out of operatory room anesthesia or Intensive Care Unit, all places where where both CO2 and fiberoptic scopes could not always be primarily or immediately available (19). When using ultrasounds, due to limitations of the technique itself, inflation with fluid together with bubbles or leaving a malleable stylet in the tube might provide the direct view of tube cuff inside the trachea (immediately below tracheal rings image) (20). This technique is not universally used or accepted, so the most important application for US to detect tracheal tube position is indirect assessment of lungs expansion. In this way, US provide a reliable and specific method to assess correct endotracheal intubation (21) by observation of correct and simultaneous expansion of both pleura, lungs (lung sliding sign) and diaphragm, thus resulting in indirect quantitative and qualitative indicators of lung ventilation and high specific confirmation (22) of correct intubation (23,24). This approach might also help in excluding bronchial intubation (pleuropulmonary and diaphragmatic movements remain unilateral) (25) or using US to assess correct selective intubation during one lung ventilation and adequate tube choice to perform selective or superselective procedures (26). Differently, if tube is positioned in esophagus or not correctly in trachea, lung expansion is not observed, and particularly the simultaneous pleural movement is missing: this results in the so called lung pulse sign, with lungs moving syncronically to hearbeat due to missed tidal-volume related cyclic expansion.

Alternative and indirect test for corrected intubation assessment is upper cervical esophagus visibility: normally US could not detect esophagus, because its virtual lumen is collapsed in absence of content: differenlty, when esophageal intubation occurs and the tracheal tube cuff is in esophagus, it becomes visible alongside the tracheal rings. To summarise, correct intubation detection could be confirmed with US either directly (but with some technical interventions with styletted tube or fluid-fille tube cuffs) or indirectly, which is the most common way to perform this test: correct intubation is confirmed with presence of some signs (lung sliding) or through their absence (no lung pulse, no esophagus visible) (27).

Finally, US might also result safe and effective in case of non operative room intubation or during patients transport or external interventions (25). New and recent studies are currently performed to assess in an evidence based manner the effectiveness and the potential role for US for correct endotracheal assessment (28), whereas actual informations seem very promising.

Applications of US for airway management: emergency cricothyrotomy

The opportunity to "see through walls" with US was highly appreciated by anesthesiologists with regiopnal anesthesia techniques and with central venous lines placement (29); following this "line", it was almost natural thinking of using US guided approach to identify cricothyroid membrane and to locate optimal puncture site for emergency cricothyrotomy.

Starting from the point that most important rea-son for failure of emergency tracheal access is difficultty to properly locate the cricothyroideal membrane, especially in obese patients and parturients (30,31), different papers have studied this opportunity on realistic models (32). Results seem promising, but probably US are not yet so promptly and commonly available to allow a full setup in useful time lags to allow a safe and effective emergency airway access, whereas the best option remains a correct and prudential preprocedural identification of potential cannot intubate – cannot oxygenate situations (33). From this point of view, preliminary US-supported airway evaluation including preliminary identification of landmarks, and specifically cricothyroid membrane, could be a great tool to practice and to increase procedural safety. As a consequence, in the setup of preoperative airway evaluation with US, cricothyroideal membrane identification should be a mandatory procedural step.

Applications of US for airway management: percutaneous tracheostomy

Differently from emergency tracheal access, preprocedural US represent a well known (34), effective, interesting and well recognised technique for elective (percutaneous) tracheotomy. US have been described to allow correct site identification for tracheostomy (35), preliminary recognition of neck masses (36) or blood vessels at risk for critical emhorrage if punctured and correct approach in relationship to a physiological (isthmus) or pathological thyroid gland (37). US might also be used to check bilateral and regular lung expansion during ventilation after the tracheostomic cannula has been inserted in position (38). On the other hand, it is important to remind that in case of percutaneous techniques, the use of US is not at all alternative for periprocedural use of fiberoptic bronchoscope, the use of which should not be abandoned, either before, during or after tracheotomy is performed.

Applications of US for airway management: pre/post-extubation evaluation

Interesting airway uses of US have been described in postoperative setting or in ICU, for evaluation of (long time) time intubated patients scheduled for weaning or extubation. US have been used to assess readiness for extubation and to try to prevent post-extubation complications. In the first case, US have been used starting from the principle that respiratory movements and excursions of the diaphragm, liver, and spleen directly correlate with respiratory muscular strength, so extubation outcome could someway be predirect in correlation with such muscles performance and endurance. Considering that US can easily explore respiratory muscles activity (39), they can be used to assess weaning performance during spontaneous/supported breathing trials and to follow-up post- extubation performance, as elegantly demonstrated in a recent paper (40).

US might also be used during extubation to assess laryngeal structures conditions, with particular reference to airway caliber and evenctual swelling/edema at vocal cords level, which might result in post extubation stridor (PES) and respiratory distress after extubation, requiring reintubation (which could also not be easy). A study by Lakhal and Coworkers (41) showed a good correlation between magnetic resonance and US airway caliber studies, and different other papers suggest US approach to increase safety for easy and non- invasive assessment of airways at extubation (42).

US for fast estimation, delivery of local anaesthetics to the airway, LMA cuff placement and other airway related procedures

Other interesting applications of US in the field of airway management might regard correct placement and cuff pressure monitoring with LMA (1, 43) or other extraglottic devices once in position, and to allow safe jugular vein cannulation with these devices in position (44). They can also be used to perform US-guided airway anaesthesia techniques for the approach to superior laryngeal nerve close to thyroid cartilage (45) and very interestingly to assess gastric content, which could be extremely used when facing full stomach patient or patients suspected for risk of aspiration, with important potential implications on anaesthesia technique to be performed (8, 46, 47).

Recently important support has come from ultrasound for endobronchial or peribronchial lung pathology, thanks to opportunity to combine bronchoscopy and echography to perform EBUS (endobronchial ultrasound) and to address trans- bronchial fine needle aspiration biopsy (TB-FNA) (48).

Future directions

Starting from the evidence of easeness of US approach, costs, instruments diffusion and lack of (known) side effects, we can easily hypothesize extended use of US in many fields of medicine, including larger applications in anesthesia. As in other technology applications a hidden risk might be represented by loss of "blind" techniques skills because of ability to perform only "US revealed" procedures; this means maintainance of traditional skills together with oriented and targeted learning of new techniques, including US approach. At the moment, probably, one of the greatest challenges faced by critical care physicians in widely adopting ultrasound is the requirement for wide- spread ultrasound education in order to reach proficiency and ensure safety; this can be (easily) obtained implementing an ultrasound curriculum in the course of training for residents, and, more challenging, education of those already in practice (5,49), who could not be prone to accept new techniques or, even worse, to be taught on something which, easy in the appearence, requires anyway a learning curve and a suffuicient practice.

In the end, we might say that US sound really good!

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ULOGA ULTRAZVUKA U PLANIRANJU I RAZVOJU STRATEGIJA ZA REŠAVANJE PROBLEMATIČNOG DISAJNOG PUTA

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Ultrazuk predstavlja jednu od najznačajnijih inovacija na polju medicine prošlog veka; zahvaljujući razvitku tehnologije, dizajnu uređaja i njihovoj portabilnosti, široko su upotrebljavani u mnogim granama medicine, uključujući i anesteziju. Osim utemeljene upotrebe kod plasiranja centralnih venskih katetera i kod izvođenja regionalne anestezije, gde je upotreba ultrazvuka značajno smanjila broj komplikacija i podigla nivo uspešnosti, ultazvuk se sve više primenjuje kod obezbeđivanja otežanog disajnog puta i to u različite svrhe. Ultrazvuk je moćno oruđe za sekundarni nivo procene disajnog puta, naročito preporučen za evaluaciju anatomskih nepravilnosti i predikciju otežanog disajnog puta. On se takođe upotrebljava za verifikaciju pozicije tubusa (naročito u urgentnim slučajevima), za identifikaciju krikotireoidne membrane, merenje dijametra glotisa pre ekstubacije, proveru pozicije uređaja za obezbeđivanje disajnog puta (kakve su laringealne maske), za izbor veličine tubusa (specijalno kod pedijatrijskih bolesnika), izvođenje procedura, kao što je traheostomija, kao i za endobronhijalnu dijagnozu bolesti pluća. U ovom radu su obrađeni osnovni principi primene ultrazvuka u menadžmentu problematičnog disajnog puta, kao i pregled literature, uključujući osnovne i proširene indikacije.

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Ključne reči: *ultrazvuk, obezbeđivanje disajnog puta, intubacija, traheostomija, krikotireoidektomija*