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PRACTICAL PEARL

Bedside Ultrasound Screening for Pretracheal Vascular Structures May Minimize the Risks of Percutaneous Dilatational Tracheostomy

Alexander C. Flint · Raghu Midde · Vivek A. Rao · Todd E. Lasman · Philip T. Ho

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Abstract

Background and Purpose Percutaneous dilatational tracheostomy (PDT) continues to gain in popularity as a bedside method for tracheostomy placement in the intensive care unit. Here, we present a description of ultrasound technique and two case examples to show the utility of bedside ultrasound screening to select patients with appropriate anatomy for PDT.

Methods We have instituted a protocol at our institution to use bedside screening ultrasound to confirm appropriate anatomy prior to PDT. In this report, we present our ultrasound methodology and present two cases with clear correlations between screening ultrasound findings and intraoperative findings.

Results We describe an easily applied method for pretracheal ultrasound screening. To show the utility of this screening technique, we then present two example cases showing pretracheal vascular structures seen on ultrasound and during open operative exploration.

Conclusion Bedside ultrasound screening allows for easy identification of pretracheal vascular structures that might pose a hemorrhage risk during PDT.

Keywords Tracheostomy · Percutaneous dilatational tracheostomy · Ultrasound screening · Hemorrhage · Bleeding · Pretracheal veins · Patient safety

Introduction

Percutaneous dilatational tracheostomy (PDT) is an increasingly popular bedside technique for tracheostomy in the ICU that has generally low risks and appears to be a cost-effective and efficient method for tracheostomy in intubated, critically ill patients [1]. PDT is being performed by an increasingly diverse of physicians, including neurointensivists [2]. A variety of techniques have been described for bedside PDT [3]. In light of the broadening of PDT operators beyond head and neck surgeons accustomed to performing operative tracheostomy, additional safeguards to minimize complications such as bleeding might be prudent. Although significant bleeding during PDT occurs infrequently [1, 4], bleeding complications of PDT from pretracheal vascular structures can be fatal [5]. Case reports of fatalities secondary to massive hemorrhage related to PDT include bleeding from pretracheal veins [6] and arteries [5, 6]. The procedure-related death rate for PDT has been estimated to be 0.6% [7], and fatalities from PDT are often from hemorrhagic complications [1, 5–10].

It has been suggested that complications related to variant vascular anatomy might be minimized by selecting patients with pre-procedural screening ultrasound, and some examples of such an ultrasound selection process have been presented in the literature [8, 11–14]. Despite these reports, screening with ultrasound prior to PDT has not yet been widely accepted as standard of care. We, therefore, describe here a simple method for bedside ultrasound screening to evaluate for pretracheal vascular

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A. C. Flint (✉) · R. Midde · V. A. Rao ·
T. E. Lasman · P. T. Ho
Neurocritical Care and Pulmonary Critical Care, Head and Neck Surgery, Kaiser Permanente, 1150 Veterans Blvd, Redwood City, CA 94063, USA
e-mail: alexander.flint@gmail.com

structures that can be easily performed prior to PDT. When pretracheal vascular structures are encountered, our approach is to exclude the patient from PDT and instead perform the tracheostomy with traditional, open operative techniques. We present two example cases in which significant pretracheal veins were identified using screening bedside ultrasound. At open tracheostomy, pretracheal veins were found to be in a location that might have caused significant bleeding if PDT had been performed.

Methods

All patients in our intensive care unit (a 16-bed mixed neurocritical care and general medical/surgical ICU) requiring tracheostomy are evaluated for possible PDT. A clinical evaluation for PDT suitability is performed, and patients with unfavorable anatomic features (such as thick, short necks, or morbid obesity) are referred for open surgical tracheostomy. Patients who are deemed potentially suitable for PDT based on this initial clinical evaluation are then screened by bedside ultrasound for the presence of pretracheal vascular structures.

Bedside ultrasound screening is performed by the intensivist with a commercially available portable ultrasound machine (M-Turbo, SonoSite Inc.) with a linear 13–6 MHz, 25-mm broadband array ultrasound probe with up to 6 cm scan depth (L25x, SonoSite Inc.). To improve tissue contrast and tissue interface detection and to reduce image speckling, vascular image optimization settings are selected and both tissue harmonic imaging (THI, SonoSite Inc.) and multi-beam spatial compounding are used (SonoMB™, SonoSite Inc.).

To decrease the chance non-visualization of veins, the patient is placed in Trendelenburg position (head down) to increase venous filling pressures in the region of interest. The head and neck are positioned in a similar fashion to that used for PDT, with a towel roll or pillow placed underneath the shoulders and the neck placed in slight extension. Care is taken throughout the screening procedure to maintain only minimal pressure with the ultrasound probe to avoid obscuration of vascular structures by probe compression. Our standard sonographic view is cross-sectional (long axis of the probe held perpendicular to the long axis of the trachea), but additional views are used to better delineate structures of interest after identification in cross-sectional images. When round, well-demarcated structures are identified anterior to the trachea that are suspicious for being vascular in nature, several maneuvers are applied to investigate whether the structures represent veins or arteries. First, compression is applied with the probe to look for lumenal narrowing in response to varying degrees of compression. Second, a Doppler cursor is placed over the structure of interest and Doppler flow is displayed graphically and audibly to screen for evidence of pulsatile or low-frequency flow signals typical of arteries or veins. Third, a square region of interest is placed around the structure and color Doppler analysis (ColorHD™ processing, Sonosite Inc.) is performed across a range of probe angles.

For this report, ultrasound still images and video clips were captured using standard software (M-Turbo, Sonosite Inc.). Intraoperative photographs and video clips were obtained using a digital camera with a close-up lens.

When PDT is performed in our ICU, we use a standard tapered dilator technique (Ciaglia Blue Rhino, Cook Medical Inc.). In brief, a 1.75 cm horizontal skin incision is made at a level corresponding to the space between the first and second tracheal rings or the second and third tracheal rings. Blunt dissection is performed with curved forceps and a gloved finger down to the level of the anterior tracheal wall. Tracheal needle access is obtained under direct bronchoscopic guidance and Seldinger over-wire tracheostomy is then performed by standard techniques.

The techniques used for open tracheostomy are described for each of the cases in "Results" section below. The extent of dissection in both cases was based on usual operative techniques and the requirements of the specific case, but the extent of dissection was not influenced a priori by findings on screening ultrasound.

Results

Ultrasound Screening

Our screening procedure for identification of pretracheal vascular structures using ultrasound are described in detail above (see "Methods" section). Basic features of the ultrasound view of the trachea and pretracheal soft tissues are shown in Fig. 1. Several anatomic features can be easily demonstrated on ultrasound imaging of the anterior neck, including the trachea itself, pre-tracheal soft tissues, the strap muscles and the sternocleidomastoids, and more laterally the carotid artery and jugular vein.

Example Cases

Patient 1

A 56 year-old man was admitted to the ICU with gallstone pancreatitis that progressed to necrotizing pancreatitis and acute respiratory distress syndrome (ARDS). Because of the need for prolonged mechanical ventilatory support, the patient was evaluated for tracheostomy. Clinical inspection revealed superficial anatomy that was amenable to

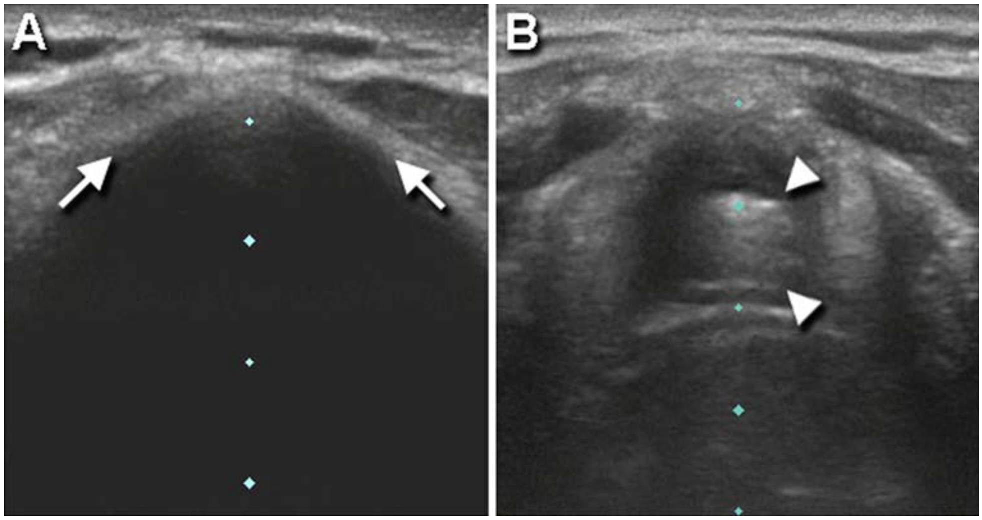

Fig. 1 Screening ultrasound evaluation prior to tracheotomy: normal anatomy. **a** Typical appearance of the trachea and pretracheal soft tissues on screening ultrasound. The anterior wall of the trachea contributes to an arch-like ultrasound boundary (*arrows*) between dense soft tissues more superficially (lighter signal) and air in the trachea below (black signal). The soft tissues overlying the trachea (above this light/dark ultrasound boundary) are screened for the appearance of any round, well-demarcated vascular structures. Any suspicious structures can be confirmed as vascular in nature by assessing for compressibility, presence of audible Doppler signal, or presence of color Doppler flow. **b** By changing the ultrasound probe angle slightly, correct identification of the tracheal lumen can be confirmed by visualization of the endotracheal tube (*arrowheads*)

tracheostomy by bedside PDT. Ultrasound screening demonstrated the presence of a network of medium-sized veins anterior to the trachea (Fig. 2a1 and a2, Supplementary Video), overlying the usual access sites used for PDT. The patient was deemed to not be an appropriate candidate for PDT, and was taken to the operating room for tracheostomy. Intraoperatively, a vein measuring 8 mm in width was found in the midline neck overlying the strap muscles (Fig. 2a3, Supplementary Video). Superiorly, two large branches fed into the central vein in a Y-shaped configuration. The dilated midline vein was dissected, transected, and suture-ligated superiorly and inferiorly. The strap muscles were bluntly retracted down the midline and the underlying thyroid isthmus was transected in the midline. Chromic sutures were used to tack portions of strap muscle to the platysma to isolate the superior portion of the ligated vein from the trachea. The inferior portion of the ligated vein was buried deep in the subcutaneous fat and strap muscles. A #8 Shiley DCT balloon tracheostomy tube was then placed via a standard tracheal window without complication.

Patient 2

An 88 year-old man with a multiple medical problems including congestive heart failure and chronic kidney disease was admitted to the ICU with pneumonia, *Clostridium difficile* colitis, septic shock, and renal failure requiring hemodialysis. After failure to wean from the mechanical ventilator, the patient was evaluated for tracheostomy. Clinical inspection did not reveal any contraindications to tracheostomy by the PDT technique. Ultrasound screening demonstrated a large vein crossing anterior to the trachea (Fig. 2b1 and b2, Supplementary Video) at the typical level for tracheostomy. Intraoperatively, a large, pulsatile vein could be seen at the edge of the right strap muscles (Fig. 2b3, Supplementary Video). Dissection was carried through the midline of the strap muscles down to the level of the cricoid cartilage. The identified vein was kept to the patient's right. It was not exposed or ligated. Once the vein was safely retracted, a #6 Shiley FEN balloon trachestomy tube was placed via a standard tracheal window without complication.

Discussion

The method presented here for ultrasound screening for pretracheal vascular structures prior to PDT is simple to perform and can identify important vascular structures that might complicate PDT. Bedside ultrasound is increasingly being used in the ICU setting in other patient-safety contexts such as ultrasound-guided central line placement. Therefore, the necessary equipment to perform such a screening step prior to PDT is commercially available and often already in use in the typical ICU. The procedure is performed by the intensivist at the bedside, and requires no more than 5 min commitment of intensivist time.

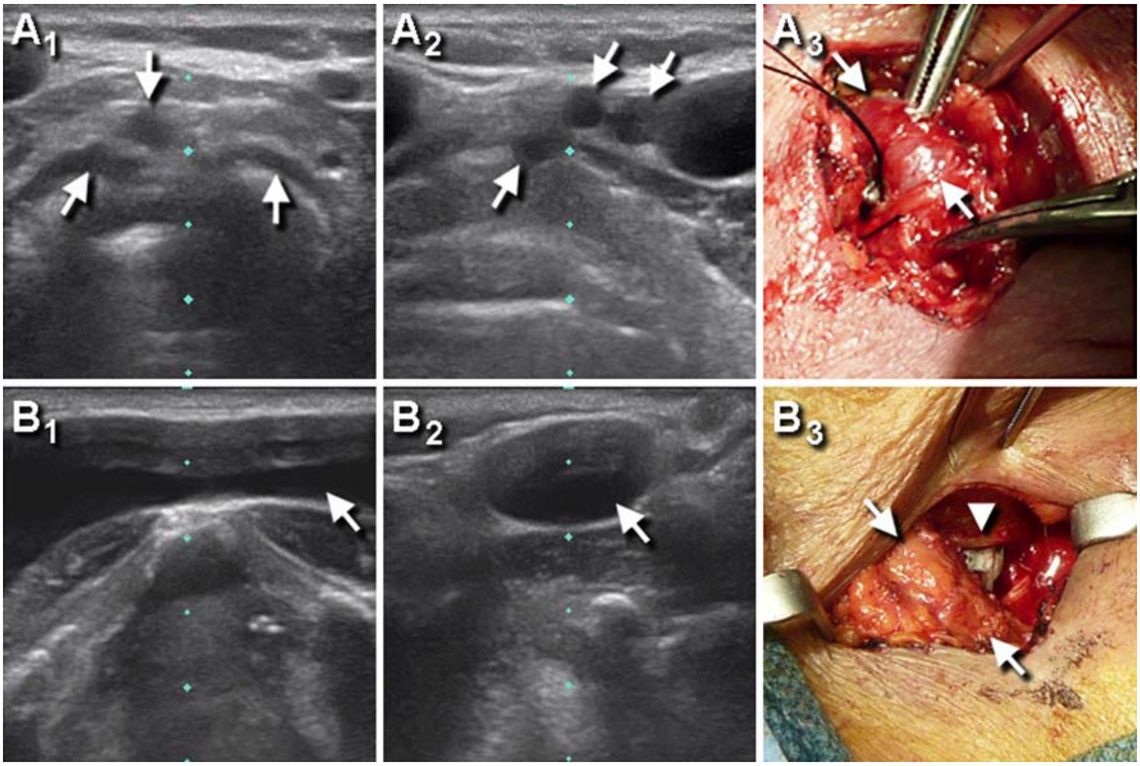

Fig. 2 Identification of pretracheal veins on screening ultrasound prior to tracheostomy. **a** Ultrasound and intraoperative findings in Patient 1. **a1** A Y-shaped vein was discovered on screening bedside ultrasound, with two veins joining to form a central vein immediately overlying the trachea in the region of the first to third tracheal rings (*arrows* indicate veins). **a2** Multiple larger veins (*arrows*) were identified further cephalad in the region of the cricothyroid membrane. **a3** A vein (*arrows*) was found to overlay the trachea in the midline intraoperatively. More superficially, larger veins were also identified (see Supplementary Video). **b** Ultrasound and intraoperative findings in Patient 1. **b1** A very large vein was identified on screening bedside ultrasound that crossed the anterior trachea obliquely (*arrow* identifies longitudinal view of vein). **b2** Same vein seen in cross-sectional view (*arrow*). **b3** Intraoperatively, a very large pulsatile vein was identified that crossed the trachea (*arrows*). (The venous nature of the structure can be best appreciated from the pulsatility seen in the Supplementary Video.) The endotracheal tube cuff can be seen through the surgical tracheal window (*arrowhead*) adjacent to and beneath the large vein

The example cases presented here provide a demonstration of veins that might have led to a higher risk of bleeding during PDT if these cases had not been screened and referred to operative tracheostomy. Operative exposure confirmed that the veins identified on ultrasound were indeed overlying the trachea. In one case (*Patient 1*), extensive operative efforts were required to avoid prolonged bleeding from the identified venous structures. The required operative manipulations such as suture ligation, vein transection, and isolation of the vein away from the tracheostomy site would not have been possible with the bedside PDT technique. It is possible that with direct ultrasound imaging during PDT, veins such as these might be potentially avoided. It is also possible that the tamponading effect of PDT (owing to minimal 'dead space' around the tracheostomy tube) might minimize bleeding from such veins during PDT. However, until further data are obtained about the relative safety of proceeding with PDT after visualization of pretracheal veins with ultrasound, the conservative approach clinically is to refer patients in this situation to open tracheostomy for the reasons described above.

Arterial structures known to be potential bleeding sources during tracheostomy such a high-riding inominate artery [6, 8, 15] should also be readily identifiable using the technique described here, as even small arteries are easily identified on vascular ultrasound, owing to features such as thicker vessel walls, pulsatility, and detection of arterial flow by Doppler analysis. To date, we have not encountered any examples of pretracheal arteries during our bedside screening process.

The current report is intended to show the feasibility of bedside ultrasound screening as a patient selection method prior to PDT, and it does not represent a methodical effort to determine the incidence of pretracheal veins or arteries in the critically ill patients requiring tracheostomy. A long-term survey will be required to estimate what percentage of potential PDT candidates are referred for operative tracheostomy because of pretracheal vascular structures found on ultrasound screening. Similarly, before–after implementation studies or other study designs would be necessary to assess whether incorporation of ultrasound screening into clinical practice reduces the risk of clinically significant hemorrhage during PDT. Prior to the availability of such data, one reasonable and conservative clinical practice is to refer patients for operative tracheostomy when pretracheal vascular structures are identified by screening bedside ultrasound. Ultrasound pre-screening may be of greatest benefit prior to standard methods for PDT, in which minimal dissection and exposure is performed (in part to create minimal ‘dead space’ around the tracheostomy tube). Methods for ‘modified PDT’ have been described [3] in which a larger incision and blunt dissection is performed that may afford greater ability to deal with encountered vascular structures. It remains to be seen what relative utility ultrasound pre-screening might have in conjunction with these specific variations on bedside PDT technique. It is possible that fewer cases might have to be referred to the operating room in centers that use the ‘modified PDT’ technique. In centers comfortable with both techniques for PDT, it would be feasible to triage patients between standard PDT, modified PDT, and open operative PDT based on the findings on ultrasound screening.

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