Use of Radio Frequency Identification (RFID) Tags in Bedside Monitoring of Endotracheal Tube Position

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Abstract:

Improper positioning of the endotracheal tube during intubation poses a serious health risk to patients. In one prospective study of 219 critically ill patients, 14% required endotracheal tube repositioning after intubation [Brunel et al. Chest 1989: 1043-1045]. While a variety of techniques are used to confirm proper tube placement, a chest X-ray is usually employed for definitive verification. Radio frequency identification (RFID) technology, in which an RFID reader emits and receives a signal from an RFID tag, may be useful in evaluating endotracheal tube position. RFID technology has already been approved for use in humans as a safe and effective tool in a variety of applications. The use of handheld RFID detectors and RFID tag-labeled endotracheal tubes could allow for easy and accurate bedside monitoring of endotracheal tube position, once initial proper placement is confirmed.

Introduction:

Attempted endotracheal intubation can lead to a number of significant problems, the two most serious being esophageal intubation and incorrect depth of insertion.[1] Early detection and correction of these problems is critical. In the case of esophageal intubation, exhaled phasic carbon dioxide is absent. This is easily detected with the use of disposable carbon dioxide measurement devices or continuous in-line monitoring of exhaled carbon dioxide.[2] As for determining the correct depth of insertion, a variety of bedside methods and X-ray imaging are employed.[3-6] Use of ballotability, commonly employed by anesthesiologists after induction of anesthesia, is not very practical in the ICU setting where this method could cause pain or unwanted elevations of blood pressure or intracranial pressure.[3] In addition, ballotability in the suprasternal notch may occur even with right main-stem intubation.[7] While X-rays remain the gold standard for confirmation of appropriate insertion depth, they are usually done only once per day.[5, 6] This may not be sufficient to detect tube migration that can frequently occur during patient care in the ICU. Caudal displacement has long been recognized as leading to right main-stem intubation and left lung collapse.[1] Cephalad displacement can lead to vocal cord injury from the endotracheal tube cuff or even to inadvertent extubation. An easy, reliable, bedside technique to confirm optimal placement, always in collaboration with good auscultation and visual inspection, would provide an important tool to improve safety in intubated patients, especially in the critical care unit.

Materials and Methods:

A Health Beacons Inc.™ RFID tag was secured to a #6.0 mm inner diameter oral Rusch endotracheal tube 1.0 cm above the proximal insertion site of the cuff using a heatshrinkable polyethylene sleeve (Figure 1C). The cylindrical tag included an antenna operating at a frequency of 134.2 kHz and a microchip and measured 12 mm in length and 2.2 mm in radius.[8] It was aligned parallel to the longitudinal axis of the endotracheal tube along its anterior border. The Health Beacons Inc.™ RFID reader, also operating at a frequency of 134.2 kHz, was a hand-held box-shaped device with an antenna and was approximately the size of a TV remote control (Figure 1A). The reader, powered by a standard 9V battery, provides an LED display that indicates relative proximity to the RFID tag (Figure 1B). The longitudinal RFID tag returns a peak signal as the reader approaches each end of the tag, and a relative minimum signal when the reader is aligned with the mid-portion of the tag (Figure 2). The employed reader was designed to accurately detect the position of the tag to a precision of a few millimeters, as long as the reader was placed within 4-5 cm of the tag.

In vitro intubation was tested on the Ambu® intubation trainer, an adult-size intubating manikin that contains anatomically correct oral and laryngeal structures. The Ambu® intubation trainer phantom was covered with an opaque piece of cloth. The endotracheal tube was placed into the trachea of the phantom. Since the RFID tag signal is most intense at each of the longitudinal ends of the tag, the RFID reader was used to bracket the location of the RFID tag. This was done by passing the RFID reader over the manikin cephalad to caudad and noting the two signal maxima locations on the cloth. This was repeated in the opposite direction as a confirmatory measure.

Results:

The RFID reader successfully bracketed the location of the RFID tag within the Ambu® intubation trainer manikin. When altering the depth of the endotracheal tube, the reader continued to successfully locate the RFID tag on the tube.

Discussion:

This demonstration shows the potential value of RFID technology for bedside monitoring of endotracheal tube depth. Using this simple technology could enhance the ability for physicians, nurses, and respiratory care personnel to perform bedside monitoring of endotracheal tubes. The application of RFID technology may decrease the frequency of required radiographs, enable early detection of malpositioned tubes, ensure early correction of malpositioned tubes, and ultimately prevent untoward complications.

In practice, once proper endotracheal tube placement is confirmed by radiography, the RFID tag location could be determined using the RFID reader. The neck could then be marked, perhaps with a permanent marking pen, to indicate the appropriate location for the RFID tag. Caregivers could confirm appropriate depth after procedures, patient transport, and patient position changes by passing the RFID reader over the mark. Adjustments in tube depth could then be made to assure that the RFID tag is aligned with the neck marking.

The concern that this technology could pose risk to the patient must be addressed. These theoretical risks could include effects of electromagnetic radiation exposure and dislodgement of the RFID tag.

The reader and tag operate at electromagnetic frequency in the low-energy range, effectively eliminating risks of interaction with human cells.[8] Furthermore, the tag itself has no baseline electromagnetic activity and only produces a signal in response to interrogation from the RFID reader. The tag works by capturing, altering, and reemitting waves sent to it by the reader.[9] The tags themselves have been approved for implantation in humans and thus far have shown no ill effects.[10]

The risk of dislodgement of the RFID tag is a manufacturing issue and may be addressed with design refinements. The tags' responses are not altered by implantation in plastic material and thus very secure confinement will not adversely affect performance. The small dimensions of the tags ensure that the size and contour of the tube will not change significantly.

One potential limitation of this technique is interference from other metallic objects that may be implanted in the neck: metal between the reader and tag can cause shielding of the interrogation signal. As far as interference with other electronic devices in the ICU and OR is concerned, the RFID system operates at low frequency (134.2 kHz) and amplitude and should not affect other adjacent equipment.

Conclusion:

Use of endotracheal tubes with attached RFID tags would allow for safe, easy, and accurate verification of endotracheal tube position immediately after intubation and throughout the duration of mechanical ventilatory support. Many of the complications of endotracheal tube positioning error could be avoided via use of bedside RFID monitoring in critical care settings. Although chest radiographs are still regarded as the standard procedure for documenting endotracheal tube position in the critical care setting after initial placement, the technology described herein provides the potential tremendous advantage of easy and inexpensive ongoing bedside monitoring without ionizing radiation. In vivo studies to evaluate clinical usefulness are warranted.

References:

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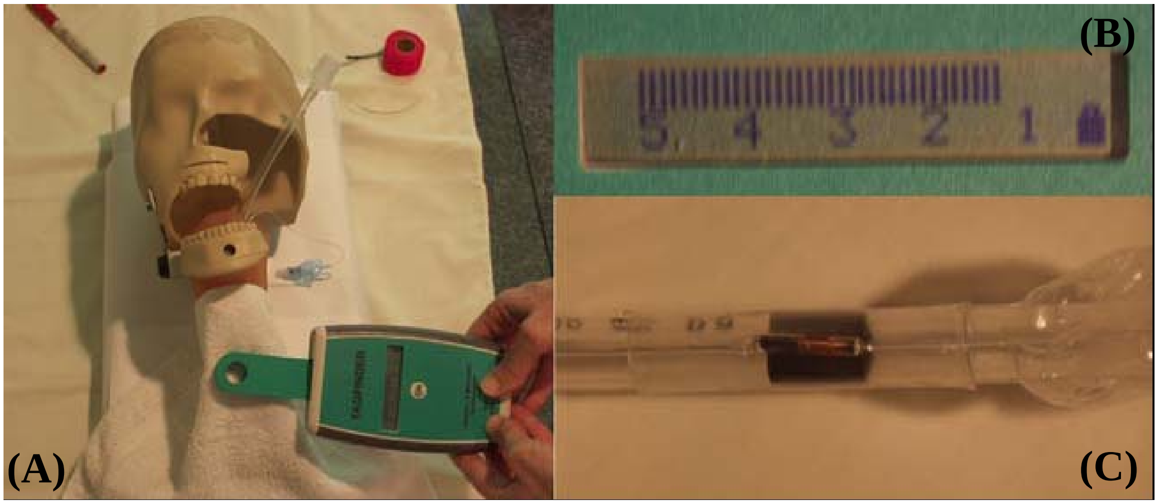

Fig. 1. (A) (Left) The RFID reader checks the position of the endotracheal tube within the Ambu® intubation trainer. (B) (Top right) The LED display on the RFID reader. A relative peak is shown. (C) (Bottom right) The small RFID tag is attached just above the balloon on the endotracheal tube.

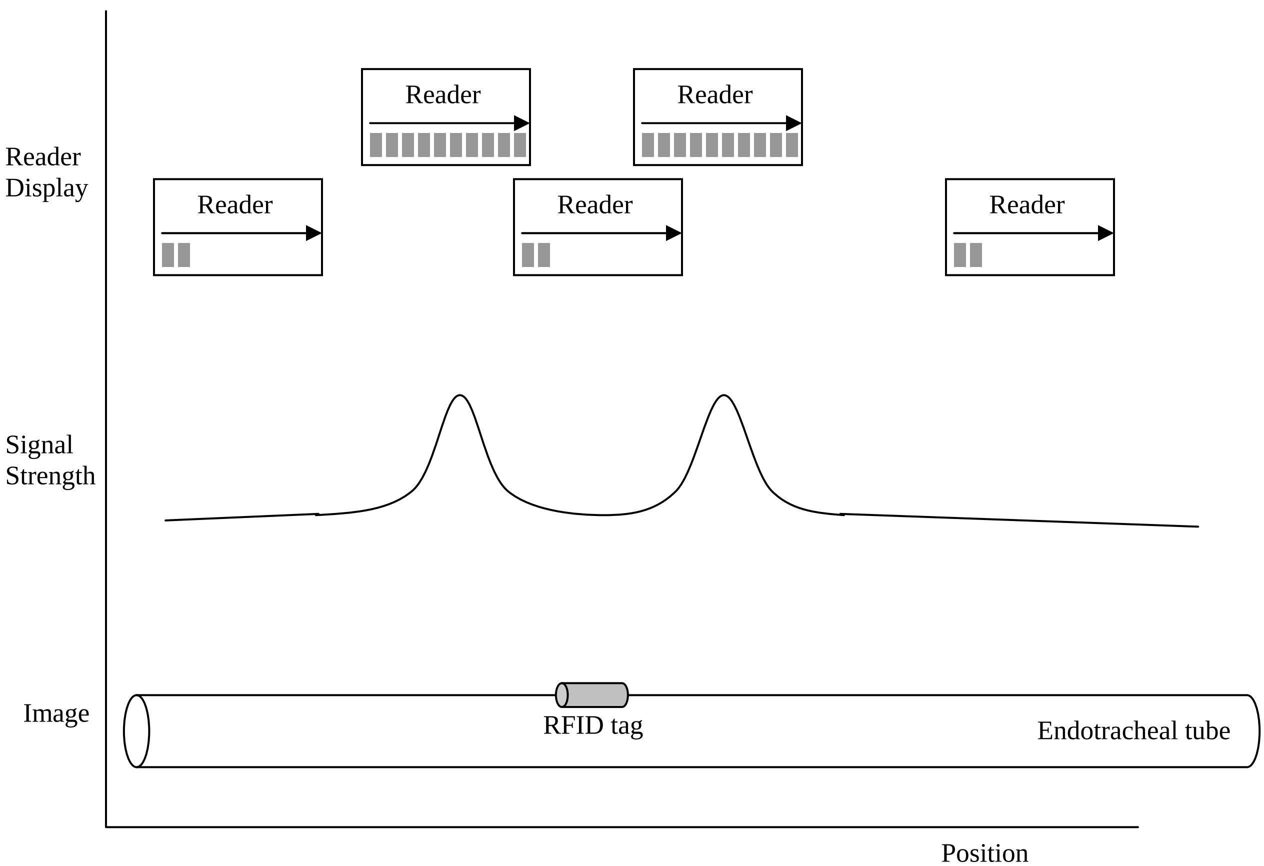

Fig. 2. The RFID reader shows signal peaks when adjacent to the longitudinal ends of the tag.