

Alternate Protocol for Frontal Radiographs to Assess Endotracheal Tube Placement Improves the Confidence of Decision-Making

Liubauskas R. MD, Litmanovich D.E. MD, Chakrala N.L. MBBS, Oren-Grinberg A. MD, Eisenberg R.E. MD

INTRODUCTION

- Following intubation, a frontal chest radiograph (CXR) is obtained to assess endotracheal tube (ETT) position by measuring the ETT tip to carina distance¹
- ETT tip location changes with neck position**, but it can be determined by assessing the position of the mandible²
- Since the mandible usually cannot be visualized on standard CXR, we developed a new protocol where the mandible is seen in the CXR
- We compared the confidence of decision-making using new and standard protocols for post-intubation CXR to assess ETT position

WHY CARE?

- An **excessively distal ETT** position could lead to endobronchial intubation, which may result in serious complications such as^{3,4}:
 - Atelectasis** of the non-ventilated lung
 - Hypoxemia, hyperinflation, and barotrauma** of the ventilated lung with possible development of pneumothorax
- A **too proximal ETT** position may lead to its displacement – caudal migration and even **self-extubation**⁵, the development of **vocal cord injury**, resulting in permanent hoarseness and significant airway obstruction³ and ETT-related tracheal rupture resulting from an overinflated ETT cuff

METHODOLOGY

Retrospective and prospective, single-center, IRB-approved study, which consisted of patients undergoing CXR following intubation to assess the position of the ETT-tip relative to the carina.

Two parts of the study:

- Part I- retrospectively assessed images obtained with the standard protocol. Patients underwent a routine supine AP post-intubation CXR for the assessment of ETT position, in which the upper margin of the image typically was in the lower neck
- Part II- prospectively included all consecutive CXRs acquired using the new post-intubation protocol. The radiology technologists palpated the mandible to ensure that 1-2 cm of this bone would be included within the upper margin of the image

What the heck is with the neck?

The position of the ETT depends on the position of the neck²:

- If the neck is extended, the ETT ascends
- If the neck is flexed, the ETT descends
- Potential movement of the ETT tip can be up to 3.8 cm in cases where neck position changes from flexed to extended or vice versa
- If the neck changes position between flexed and neutral, or between neutral-extended, the potential movement of the ETT tip is ~1.9 cm

In the study^{2,6}:

- The neck is considered extended if the mandible projects over C4 or higher
- The neck is considered neutral if the mandible projects over C5 or C6
- The neck is considered flexed if the mandible projects over C7 or lower

Where do we want the ETT to be?

The desired position of the ETT depending on the neck position⁶ (Figure 1; A, B, C):

- With the neck flexed – the ideal position of the ETT tip is 3 ± 2 cm above the carina
- With the neck neutral – the ideal position of the ETT tip is 5 ± 2 cm above the carina
- With the neck extended – the ideal position of the ETT tip is 7 ± 2 cm above the carina

We can be uncertain sometimes

We established “gray-zone” values (Figure 1) at which the CXR are difficult to assess whether the ETT is in a satisfactory position if the mandible is not visible:

- If the ETT tip-carina distance is >9 cm, then the ETT is too high, regardless of the neck position
- If the ETT tip-carina distance is <1 cm, then the ETT is too low, regardless of neck position
- If the ETT tip-carina distance is 6.0–9.0 cm, then the ETT is in a high **gray-zone** position
- Rationale:** if the neck is extended at the time the CXR was obtained, the ETT is positioned appropriately. If the neck is flexed, the ETT may move upwards with the neck in a neutral or extended position, resulting in a too high ETT position
- If the ETT tip-carina distance is 1.0-4.0 cm - the ETT is in a low **gray-zone** value
- Rationale:** if the neck is flexed at the time the CXR was obtained, the ETT would be positioned appropriately. If the neck is extended or neutral, the ETT may potentially move downward, resulting in a too low position of the ETT

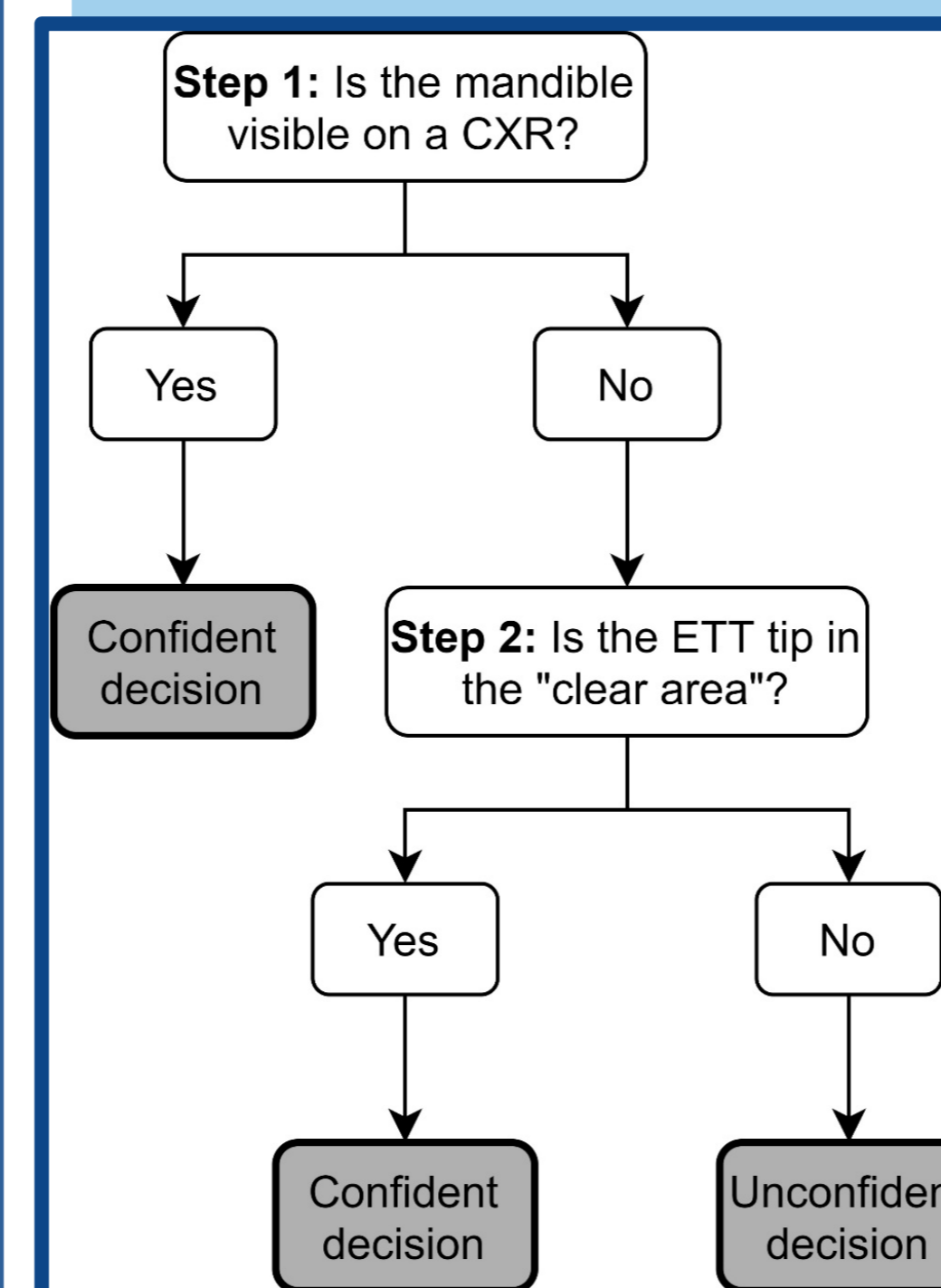


Fig. 2 – Algorithm to assess the ETT position

Making a confident decision

Algorithm for assessing the ETT position (Fig. 2):

- Step 1** – is the mandible visible on the CXR?
- If so, the position of the neck, and therefore the ETT position, can be confidently assessed. No additional steps
 - If the mandible is not visible, go to step 2
- Step 2** – is the tip of the ETT is in one of the clear-zones?
- If so, the ETT position can be confidently assessed regardless of the neck position
 - If not, the ETT position cannot be confidently assessed

Other times we're sure

- Based on the “gray zones” - only when the ETT tip-carina distance is 4.0-6.0 cm, can the reader be confident that the ETT position is satisfactory regardless of the neck position
- When the ETT tip-carina distance is either >9.0 cm or <1.0 cm, the reader can be confident that the ETT position is unsatisfactory regardless of neck
- We established these ranges (<1.0 , **4.0-6.0**, >9.0 cm) as “clear-zone” values, because the reader can confidently recommend moving or leaving the ETT in the current position

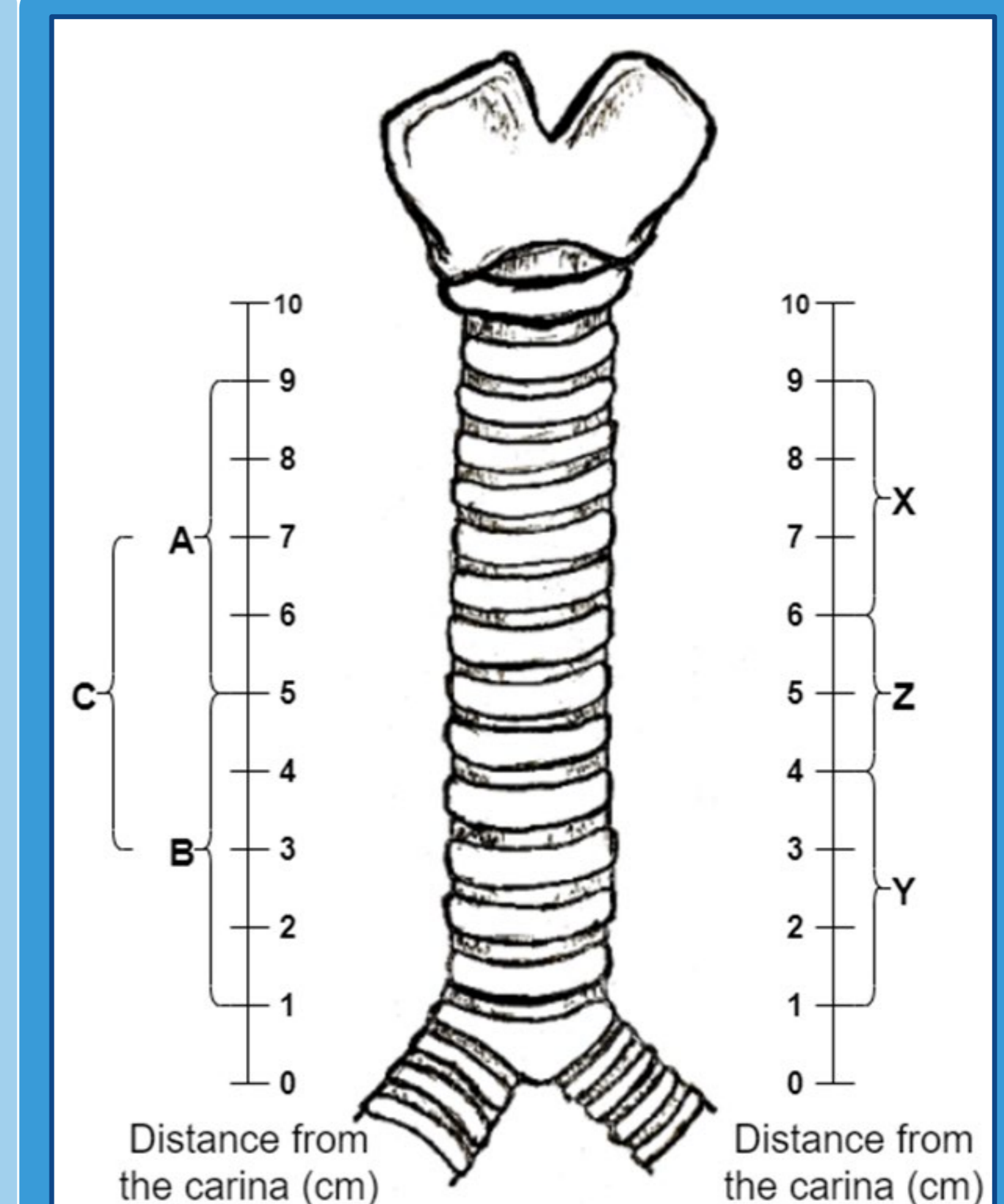


Fig. 1 – Summary of different ranges of the ETT tip – carina
 A – appropriate range of ETT tip when neck extended (5-9 cm)
 B – appropriate range of ETT tip when neck flexed (1-5 cm)
 C – appropriate range of ETT tip when neck neutral (3-7 cm)
 X – Gray zone of the ETT being potentially too high (6-9 cm)
 Y – Gray zone of the ETT being potentially too low (1-4 cm)
 Z – Clear zone regardless of the neck position (4-6 cm)

Which zone is what now?

“GRAY ZONE” – ETT tip–carina distance, at which it is difficult to assess whether the ETT is in a satisfactory position if the mandible is not visible

“CLEAR ZONE” - ETT tip–carina distance, at which the reader can confidently recommend retracting, advancing or leaving the ETT in the current position

NB! - clear zone does not mean that the ETT position is satisfactory, but that the reader can distinctly determine whether the position is satisfactory or requires adjustment.

Alternate Protocol for Frontal Radiographs to Assess Endotracheal Tube Placement Improves the Confidence of Decision-Making

Liubauskas R. MD, Litmanovich D.E. MD, Chakrala N.L. MBBS, Oren-Grinberg A. MD, Eisenberg R.E. MD

RESULTS

- There were 308 patients in the study with post-intubation CXR – 155 using the standard technique and 153 using the new protocol
- Based on the mandible position, the neck was in neutral (45%; 78/173), extended (45%; 77/173) or flexed (10%; 18/173) positions
- There was a significant increase ($p < 0.001$) in visualization of the mandible on post-intubation CXR obtained with the new protocol (92%; 141/153) compared to those with the standard technique (21%; 32/155).
- The distribution of mandible visibility and zones is summarized in table 1 and figure 3.

	ETT* position	Standard Protocol	New Protocol
Mandible Visible	Certain	32 (21%)	141 (92%)
Mandible Not Visible	Clear zone	48 (31%)	7 (5%)
	Gray zone	75 (48%)	5 (3%)
	Total	155 (100%)	153 (100%)

Table 1 - Overview of the study results

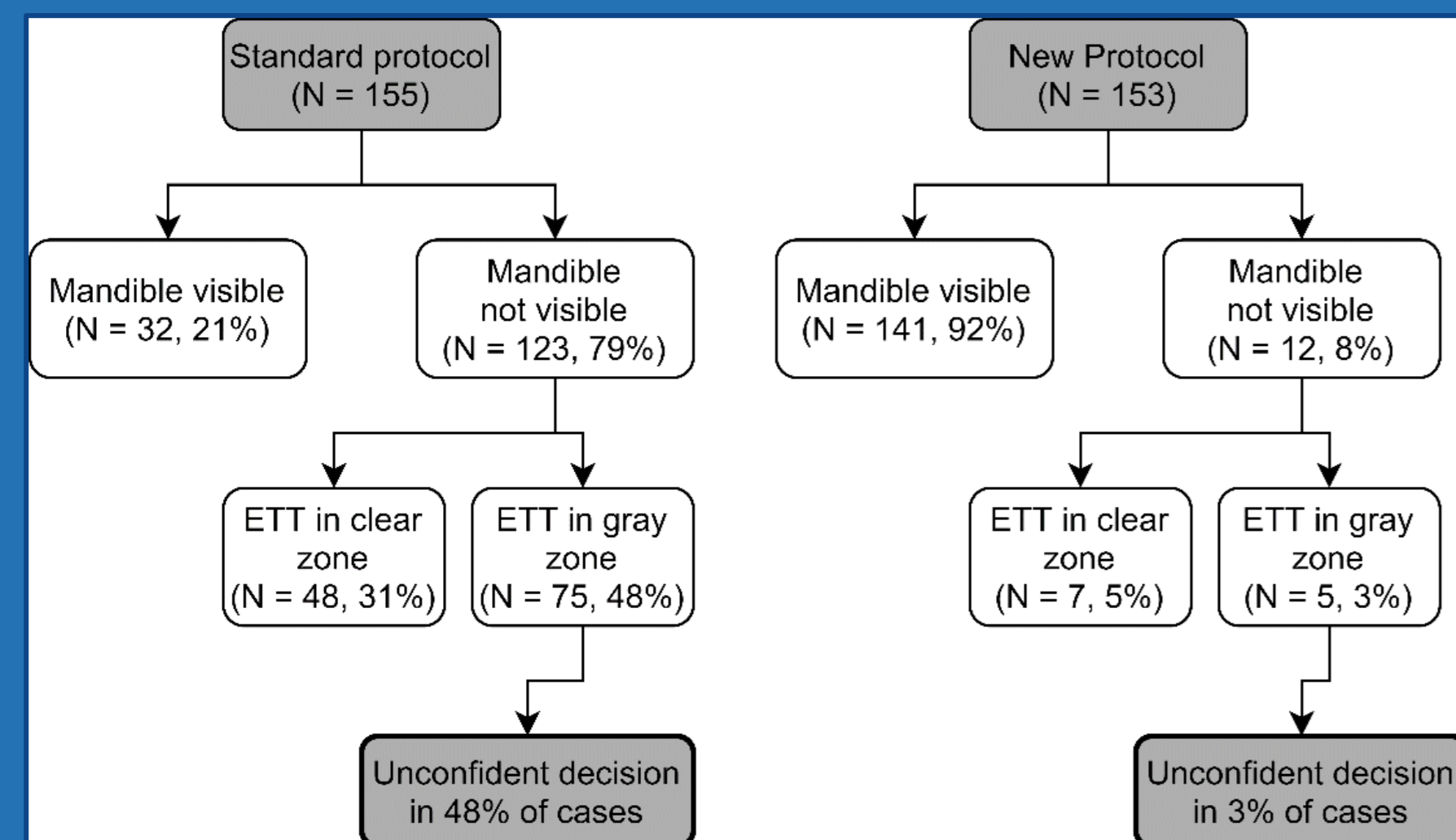


Figure 3 - Using the standard protocol, there was an unconfident decision rate of 48%, compared with only 3% using the new protocol.

- When the mandible was visualized, it most commonly projected over the C5 (32%; 56/173) or C4 (25%; 44/173) vertebral body, with a range of C1-T2, suggesting that the neck is usually in a neutral or slightly extended position (Figures 5 and 6).

EXAMPLES FROM YOUR PRACTICE TODAY!

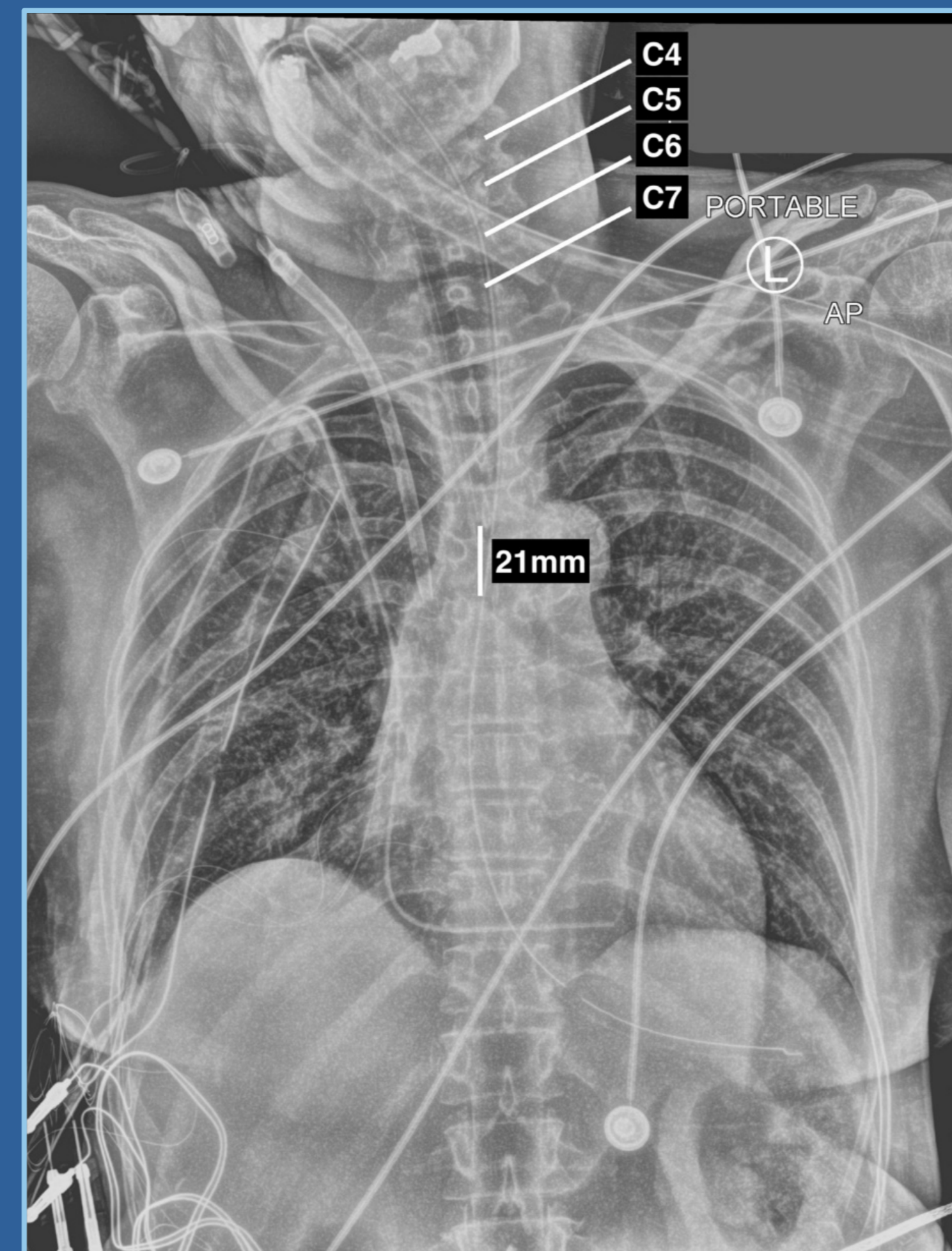


Figure 5 – Inaccurate interpretation of the ETT position based on shape and angle of the mandible. 55-year-old woman following intubation with ETT tip 2.1 cm above the carina. Recommendation to retract the ETT was not made. Based solely on the shape of the mandible, the neck may appear flexed. Assessing by the relationship of the vertebral body to the mandible, neck may be extended (mandible projects over C4), introducing the risk of ETT descending by approximately 2-4 cm depending on neck movements, and possibly intubating the right bronchus.

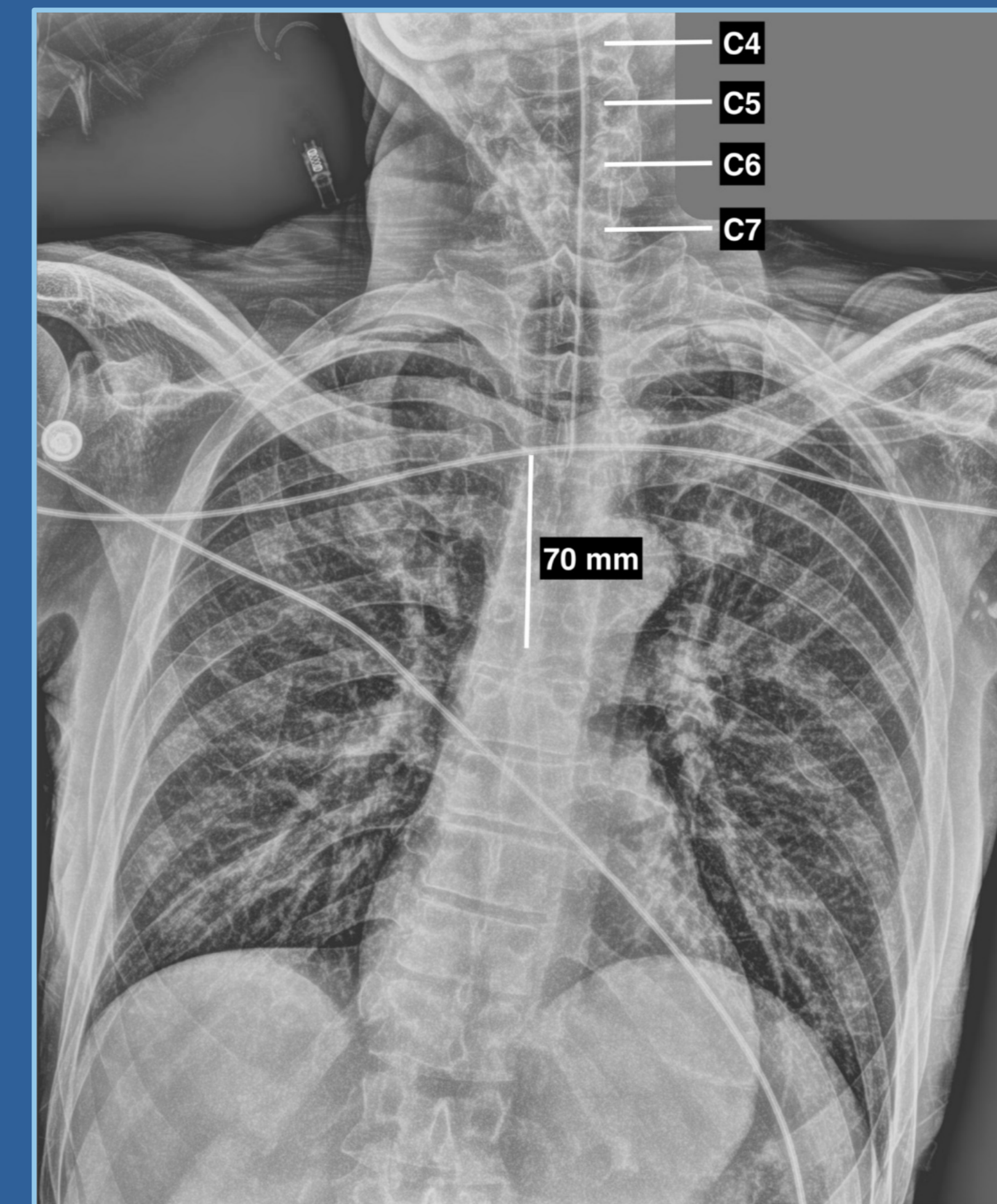


Fig. 6 – Inaccurate interpretation due to failure to assess the relationship of the mandible to the vertebral bodies. In this 66-year-old man following intubation with ETT* tip 7.0 cm above the carina, it was recommended to advance the ETT. However, in assessing the relationship of the mandible to the vertebral bodies, the neck appears to be in an extended position (mandible projects over C3-C4), making the position of the ETT appropriate, as it may descend 2-4 cm depending on neck movements

RESULTS

- There were two acceptable ways to determine whether the ETT was in the appropriate position: by visualizing the mandible, or by observing the ETT in the clear zone.

Combining both measures, we have estimated that a confident decision can be made in 96.7% of cases using the new protocol, compared to 51.6% of cases using the standard protocol ($p < .001$) (Figure 4).

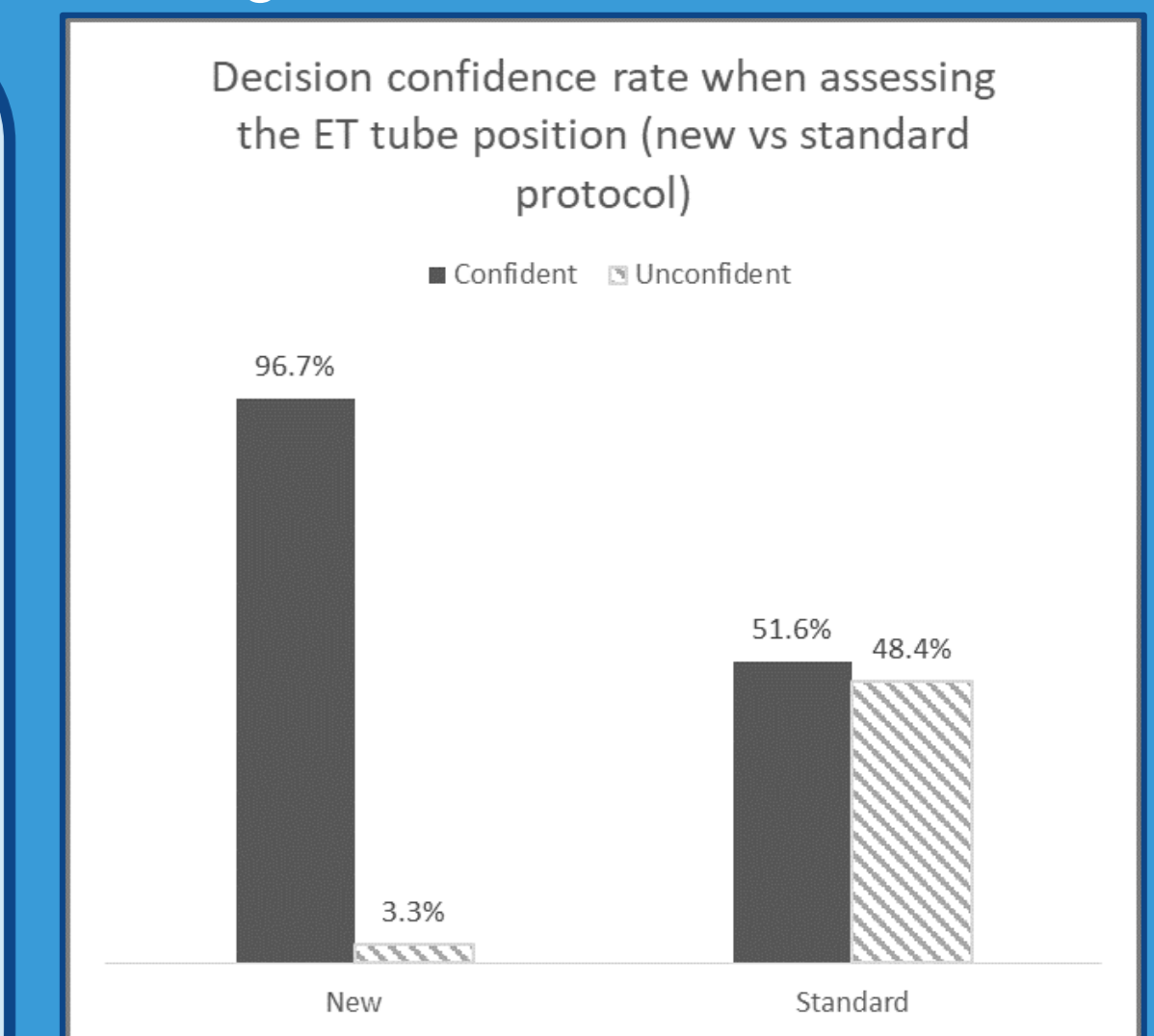


Fig. 4 - Decision confidence rate when assessing ETT position (new vs standard protocol)

CONCLUSION

To our knowledge, this study is the first study to demonstrate that mandible inclusion on post-intubation CXR is a simple and cost-effective method to ensure proper assessment of the ETT position, sparing the patients from unnecessary additional imaging and almost doubling the level of certainty of the decisions made by the radiologist.

REFERENCES

1. Godoy MC, Leitman BS, de Groot PM, Vlahos I, Naidich DP. Chest radiography in the ICU: Part 1, Evaluation of airway, enteric, and pleural tubes. *AJR Am J Roentgenol.* 2012;198(3):563-71.
2. Conrardy P, Goodman L, Lainge F, Singer M. Alteration of endotracheal tube position. Flexion and extension of the neck. *Crit Care Med.* 1976;4(1):8-12.
3. Mathew R, Alexander T, Patel V, Low G. Chest radiographs of cardiac devices (Part 1): Lines, tubes, non-cardiac medical devices and materials. *SA J Radiol.* 2019;23(1):1729.
4. Owen RL, Cheney FW. Endobronchial intubation: a preventable complication. *Anesthesiology.* 1987;67(2):225-7.
5. Kearn RA, Hooper RG. Massive airway leaks: an analysis of the role of endotracheal tubes. *Crit Care Med.* 1993;21(4):518-21.
6. Goodman L, Conrardy P, Laing F, Singer M. Radiographic evaluation of endotracheal tube position. *AJR Am J Roentgenol.* 1976;127(3):433-4.