

From Reactive Correction to Predictive Personalization: The Next Frontier in Endotracheal Tube Cuff Pressure Management at the Point of Care

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Dear Editor

As the corresponding author of the published study entitled “Effect of Body Position Change and Vital Signals on Endotracheal Tube Cuff Pressure Variations” (1), we wish to reflect on our findings and propose a forward-looking roadmap for achieving the highest standard of point-of-care (POC) management in mechanically ventilated pediatric patients. Our multidisciplinary team has consistently emphasized integrating hemodynamic and positional variables into critical care decision-making, particularly in vulnerable populations following congenital cardiac surgery (2).

Our study confirmed that positional changes significantly elevate endotracheal tube cuff pressure (ETCP) in children following Glenn shunt surgery, with marked increases observed in the right lateral positioning at 30° and 45° ($p < 0.001$). While we strongly recommended routine ETCP checks after every repositioning, we now believe this recommendation, though clinically essential, represents only a reactive safety net, rather than a proactive safety system. Recent evidence indicates that despite established guidelines recommending ETCP maintenance within 20–30 cmH₂O, no universally accepted monitoring frequency exists, and manual checks remain prone to error (3).

To move beyond our current contribution toward the optimal point of care, we propose four paradigm-shifting directions:

1. From Intermittent to Continuous Closed-Loop Control

Our use of an analog manometer, while validated, introduced inherent reading errors and allowed pressure drift between measurements. An IoT-enabled automated cuff pressure controller has been developed with closed-loop capabilities at a fraction of the cost of commercial devices, demonstrating performance comparable to gold-standard manometers (4). However, since this study primarily focused on engineering design and technical validation, we advocate structured, prospective clinical validation studies to evaluate the accuracy, response time, and fail-safe mechanisms of these IoT-enabled closed-loop devices across diverse ICU populations. Such studies should assess device performance under extreme positional changes and varying ventilator settings before any broad clinical recommendation can be made. We therefore encourage the research community to prioritize engineering–clinical collaborative trials that bridge the gap between technical validation and bedside applicability.

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2. Developing Predictive Algorithms Using Machine Learning

Our data showed that mean arterial pressure (MAP) correlated with ETCP only in specific positions. However, we did not model this relationship dynamically. Our group has previously demonstrated the utility of artificial neural networks for estimating clinical parameters from vital signs (2), supporting the feasibility of predictive modeling in critical care settings. We now advocate training predictive models that incorporate baseline ETCP, bed angle, MAP, heart rate, and ventilator parameters to forecast pressure changes before position changes are executed, transforming practice from "measure after moving" to "know before moving." Notably, a prospective study of 199 surgical patients found that 96% experienced ETCP alterations outside the appropriate range during surgery, with positional changes identified as a primary causative factor, reinforcing the need for predictive approaches (5).

3. Individualizing Targets via Anatomical Profiling

We acknowledged the limitation of ignoring inter-individual differences in tracheal anatomy. A truly personalized POC approach would utilize bedside point-of-care ultrasound (POCUS) to measure tracheal diameter and cuff-to-vocal cord distance prior to intubation. However, it is critical to distinguish between endotracheal tube size selection (which is determined by tracheal diameter to ensure proper fit and prevent air leakage) and cuff pressure management (which depends on intracuff air volume and tracheal wall compliance, rather than tube size per se). While ultrasound can optimize tube size selection (6,7), the direct relationship between tube diameter and cuff pressure remains complex and requires further investigation. Notably, a recent study by Ban et al. demonstrated that endotracheal tube size is an independent risk factor for inadequate cuff pressure, with smaller tubes (ID 6.0) showing significantly higher intracuff pressures compared with larger tubes (ID 8.0) (41.9 ± 18.8 vs. 30.3 ± 11.9 cmH₂O, $p < 0.001$) (8). This finding confirms that even appropriately sized tubes can generate excessive cuff pressure if inflated without manometry, and that smaller tube sizes may further increase this risk. Therefore, while adult data (6) support the conceptual framework for personalized tube selection, we emphasize that pediatric-specific normative reference values for both tube sizing and cuff pressure targets are urgently needed before routine POCUS-guided management can be implemented in children.

4. Integrating Drug–Position–Pressure Interactions

Our study did not account for vasoactive infusions are ubiquitous in post-cardiac surgery patients. Future trials should stratify ETCP changes based on inotrope and vasopressor dosing, as these agents directly influence tracheal smooth muscle tone and may modulate the positional effect we observed. MAP alone is an insufficient proxy. Vasopressin, increasingly used as adjunctive therapy in septic shock to reduce catecholamine requirements, acts via V1 receptors, inducing vasoconstriction without significantly increasing myocardial oxygen consumption (9,10). The interaction between these agents and tracheal smooth muscle tone warrants systematic investigation.

Our original study provided evidence that position changes affect ETCP, a finding replicated across ICU populations. However, the true point of care lies not in periodic correction, but in anticipatory, automated, and individualized management. We invite the research community to design multicenter trials comparing closed-loop, algorithm-driven cuff management against standard manual protocols, with patient-centered outcomes such as post-extubation stridor, ventilator-associated pneumonia, and ICU length of stay. Only by embracing integrative, technology-enhanced approaches informed by insights from the critical care team can we elevate pediatric critical care from a reactive discipline to a genuinely predictive and precise science.

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