Moving the Goalposts: An Evidence-based Updated Framework for Postanesthesia Apnea Risk in Neonates and Infants

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Risk and management of postanesthesia apnea in infants, particularly those born preterm, remains a source of persistent clinical anxiety and practice variability. Determining when a former preterm infant is "safe" for discharge is typically protocolized at an institutional level, based largely on historical data, with deviations driven by individual clinical judgment, anecdotal experience, and perceived risk. However, for many pediatric anesthesiologists, modern practice increasingly feels misaligned with these historical goalposts. This growing cognitive dissonance between protocolized thresholds and bedside experience has created the need for contemporary recalibration of risk.

In this issue of Anesthesiology, Dalal *et al.*[1,2] present two complementary and timely studies that together comprehensively revisit the field by analyzing newer available data. The first is a bird's eye systematic review and meta-analysis of postanesthesia apnea in former preterm and term infants[1]; the second is a rigorous individual participant data (IPD) meta-analysis focused on former preterm infants undergoing inguinal herniorrhaphy.[2] Together, these studies reanalyze the available evidence base and offer an updated, more coherent, quantitative, and clinically actionable framework for decision-making for risk assessment and management of postanesthesia apnea in neonates and infants.

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The significance of these studies is best appreciated in historical context. Thirty years ago, Coté *et al.*[3] conducted the first combined analysis of prospective studies on postanesthesia apnea, concluding that that apnea risk did not fall below the "clinically acceptable" 1% threshold until approximately 57 weeks postmenstrual age (PMA). This has guided clinical decision-making for postoperative care in this population. However, this was derived in an era that predates many of the anesthetic techniques, monitoring strategies, and perioperative practices that now define contemporary care. The current work by Dalal *et al.*,[1,2] notably including Dr. Coté as a coauthor, represents a timely and thoughtful reexamination of that framework using a far larger data set and more sophisticated analytic methods.[4]

The systematic review[1] confirms that PMA at the time of anesthesia remains the dominant and most consistent predictor of postanesthesia apnea. At the same time, it demonstrates a clear temporal trend toward lower reported event rates over nearly four decades, likely reflecting genuine improvements in anesthetic management, monitoring, and perioperative care. The observation that neuraxial anesthesia is associated with lower odds of apnea than general anesthesia adds further support to a long-standing but incompletely quantified clinical intuition. However, this observation must

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Table 1. Updated Incidence of Postanesthesia Apnea in Neonates and Infants

General Anesthesia	Neuraxial Anesthesia
~10% risk at 53 weeks PMA	~10% risk at 38 weeks PMA
~5% risk at 57 weeks PMA	~5% risk at 40 weeks PMA
~1% risk at 65 weeks PMA	~1% risk at 45 weeks PMA

PMA, postmenstrual age.

be interpreted cautiously given the predominantly observational nature of the underlying literature.

The accompanying IPD meta-analysis[2] moves the field from simple association to calibration of risk. By pooling raw data from 12 prospective studies in former preterm infants undergoing inguinal hernia repair, the authors estimate clinically meaningful PMA thresholds associated with approximately 10%, 5%, and lower than 1% risks of postanesthesia apnea (table 1). For preterm infants receiving general anesthesia, the less than 1% risk threshold occurs at approximately 65 weeks PMA—significantly later than the 50- to 60-week window many clinicians currently use.

In contrast, with neuraxial anesthesia, the same threshold is reached near 45 weeks PMA. This massive 20-week disparity suggests that our current monitoring cutoffs may be overly cautious for some and potentially insufficient for others, depending to a large degree on the anesthetic plan.

The historical significance of the 1% threshold is that it has long served as the implicit benchmark for same-day discharge. In pediatric anesthesia, a risk exceeding 1% for a potentially life-threatening event such as apnea is generally considered unacceptable for unsupervised care at home, where caregivers are neither trained nor equipped to provide rescue ventilation. By requantifying the PMA at which this boundary is crossed for different anesthetic techniques, Dalal *et al.*[1,2] provide a transparent and defensible evidence-based foundation for postoperative disposition decisions for each patient's individual risk profile.

It is also important to emphasize what these analyses do not offer or suggest: a single, pooled "overall incidence" of postanesthesia apnea. This single number would be clinically meaningless. The absolute frequency of events is strongly nonlinear with postmenstrual age and is profoundly modified by anesthetic technique and patient factors. In practical terms, contemporary data suggest that the observed incidence in former preterm infants spans roughly an order of magnitude, from approximately 1% in older, lower-risk infants to 5 to 10% in younger, higher-risk strata, depending primarily on postmenstrual age and anesthetic approach. This steep risk gradient also explains why many clinicians perceive apnea to have become "rare": most current practice is already concentrated in the older, lower-risk infants, in whom the absolute event frequency has already collapsed toward or below the 1% range, and clinicians may then personally observe one or two postanesthesia apnea events a year and underappreciate the nuanced risks reported herein.

Beyond age and technique alone, these studies identify other risk factors that should immediately inform clinical practice. While birth weight, prematurity, and history of apnea remain strong predictors, the authors identify procedure duration as a significant, independent risk factor. This prompts a difficult clinical question: what duration is truly "meaningful?" While the meta-regression establishes a linear relationship (odds ratio, 1.22 for every additional 15 min of surgery), the studies do not provide a binary "safe" cutoff. For the clinician, this means that longer anesthesia counts. Surgical strategies that minimize operative time, such as two-surgeon bilateral repairs, become direct safety interventions rather than mere issues of efficiency. Meanwhile, the relationship between anemia and apnea risk (at least in preterm infants undergoing general anesthesia for herniorraphy) is now seen to be more nuanced, with a hemoglobin concentration of less than 10 g/dl not contributing materially to risk before 48 weeks PMA.

For the practicing clinician, the combined message of these two articles is both reassuring and challenging. Reassuring, because they confirm that risk is quantifiable and largely predictable from PMA and modulated by anesthesia technique and patient factors. Challenging, because they also highlight that many current institutional practices, often based on historical cutoffs or local customs, are misaligned with the now best available evidence but likely in a direction that is *opposite* to what might have been believed. The IPD analysis provides a modern, data-driven, updated, and defensible framework for discussing postoperative monitoring and admission decisions with surgical colleagues, hospital administrators, and families (while acknowledging that IPD data pertain only to inguinal hernia repairs).

These findings also force us to reconsider the timing of surgery. If general anesthesia carries a greater than 1% apnea risk until 65 weeks PMA, should we further delay elective procedures? In the case of inguinal hernias, the risk of incarceration often precludes waiting until an infant reaches 6 months of corrected age. However, for truly elective, nonurgent procedures, the data of Dalal *et al.*[1,2] provide a strong argument for waiting until the 65-week mark to simplify the perioperative course. When delay is not an option, the postanesthesia apnea risk of the procedure must be mitigated through anesthesia technique choice, shorter surgical times, or guaranteed overnight monitoring.

The clinical implications translate into two substantial practical challenges for the coordination of perioperative care and short-stay units. A 65-week threshold for day-case general anesthesia and a 24-h postanesthesia monitoring requirement creates a significantly greater burden for hospitals where postanesthesia care units (PACUs) are not designed for extended observation. A procedure under general anesthesia effectively mandates an inpatient admission or an overnight PACU stay, both of which disrupt standard

workflows and may strain staffing. A critical nuance identified in the Dalal *et al.*[1,2] IPD analysis is that the physiologic benefit of neuraxial anesthesia is primarily front-loaded. While spinal and caudal techniques substantially reduce the odds of early apnea, the risk of late apnea is strikingly similar to that seen after general anesthesia.

Consequently, these findings argue for a "morning-only" scheduling policy for high-risk infants to allow for an adequate observation window followed by next-day discharge early enough to free up resources for that next day's workload or a more aggressive shift toward neuraxial techniques to facilitate both earlier safe discharge (12 h of postanesthesia monitoring) and a 45-week PMA threshold for day-case inguinal hernia repair surgery.

However, neuraxial anesthesia is not always straightforward. Neuraxial techniques require specific expertise, have a meaningful failure rate, may be unsafe in the presence of coagulation abnormalities and impose surgery duration constraints. While the benefit of postanesthesia apnea risk reduction is clear, these potential drawbacks still necessitate a readiness for conversion to general anesthesia; this immediately resets the risk profile and necessitates the longer 24-h monitoring window suggested by the data. Emerging evidence suggests that dexmedetomidine infusion combined with high-flow oxygen may offer a viable sedative adjunct to neuraxial blocks to reduce respiratory complications; however, conversion rates to general anesthesia remain noteworthy.[5]

These data also raise an uncomfortable concern about whether some infants thought to be beyond the historically accepted 57-week PMA risk window but less than the newly suggested 65-week PMA threshold are experiencing apneic episodes at home that go unrecorded. Current recommendations are based on events observed in the hospital, but the fact that the first apnea can occur up to 14 h after anesthesia suggests that some patients currently discharged after meeting standard institutional PACU criteria may indeed be at risk in their own cribs. Until home-monitoring studies provide clarity, our safety thresholds remain "hospital-centric" and perhaps incomplete.

This work does not eliminate uncertainty, but it meaningfully narrows the range of reasonable disagreement. By updating and refining quantified risk with increased granularity, Dalal *et al.*[1,2] increase the evidentiary foundation for decision-making in one of pediatric anesthesia's most anxiety-provoking domains. They also point the direction to some of the next generation's research questions in this field. Do anesthetic techniques such as regional/caudal + total intravenous anesthesia, which combine surgical deafferentation with maintenance of spontaneous respiration, reduce or eliminate the risk of postanesthesia apnea? How do lower accepted hemoglobin levels and restrictive neonatal intensive care unit transfusion strategies affect risk? What combination of postoperative monitoring modalities offers the best balance between detection and practicality? Standardizing and advancing our monitoring strategies will be essential to move this field forward. Until home-monitoring studies provide clarity, however, our safety thresholds must remain unapologetically hospital-centric, based on the simple reality that rescue ventilation must be immediately available for infants whose quantified risk still exceeds what can reasonably be tolerated at home.

The potential value of a multicentre prospective registry approach to obtaining the data to answer these questions is worth considering. In the meantime, the rules on safety first are unchanged, but the goal posts may have been moved.

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