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THE ROLE OF THE ANESTHESIOLOGIST IN PEDIATRIC INTENSIVE CARE UNIT: A NARRATIVE REVIEW

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ABSTRACT

Background: The Pediatric Intensive Care Unit (PICU) manages critically ill neonates, infants, and children with complex physiological derangements. Anesthesiologists, by virtue of their specialized training in pediatric physiology, pharmacology, airway management, and perioperative medicine, are uniquely positioned to contribute to high-quality PICU care. **Methods:** This narrative review synthesizes evidence from major anesthesiology and critical care journals to evaluate the role of Anesthesiologists in the PICU. The review focuses on key domains of pediatric critical care practice in which Anesthesiologists have substantial impact, including airway management, mechanical ventilation, hemodynamic support, sedation and analgesia, and perioperative critical care encompassing both intraoperative and postoperative management. In addition, the review highlights the role of Anesthesiologists in multidisciplinary leadership, emphasizing their contribution to team coordination, protocol implementation, and overall quality of care in the PICU setting. **Results:** The literature consistently demonstrates that Anesthesiologist involvement in the PICU is associated with significant improvements in multiple clinical domains. These include enhanced airway safety through advanced airway management skills; optimized ventilation strategies tailored to pediatric patients—particularly in hypoxemic and hypercapnic respiratory failure—and improved pain and sedation control through individualized pharmacologic approaches. Furthermore, Anesthesiologists contribute to better continuity of care across the perioperative period, ensuring seamless transition from intraoperative management to postoperative critical care. These benefits are particularly evident in specific pediatric populations. Postoperative pediatric surgical patients, especially those undergoing correction of congenital anomalies such as tracheoesophageal fistula and congenital diaphragmatic hernia (including Bochdalek and Morgagni types), frequently require specialized ventilatory and hemodynamic support. Similarly, children with cardiovascular compromise, including those with dilated cardiomyopathy or heart failure, benefit from precise hemodynamic monitoring and targeted therapeutic interventions provided by Anesthesiologists. In addition, pediatric patients with respiratory failure represent a major group in which Anesthesiologist expertise is critical; this includes hypoxemic respiratory failure, commonly seen in conditions such as bronchiolitis and pneumonia, as well as hypercapnic respiratory failure associated with severe asthma. Neuromuscular disorders, including Guillain–Barré syndrome and myasthenia gravis, further highlight the importance of specialized ventilatory management and pharmacologic considerations in the PICU. **Conclusion:** Anesthesiologists play a key role in the PICU, contributing expertise in airway management, ventilation, hemodynamic support, and sedation tailored to pediatric physiology. Their involvement improves patient safety, perioperative continuity, and clinical outcomes, particularly in high-risk groups such as postoperative patients and those with respiratory or cardiovascular compromise. Strengthening pediatric critical care training within anesthesiology is essential to optimize the PICU care.

KEYWORDS: Airway management, anesthesiology, hemodynamics, perioperative care, Pediatric intensive care unit, sedation, ventilation.

1. INTRODUCTION

The Pediatric Intensive Care Unit provides advanced life support for critically ill neonates, infants, and children presenting with conditions such as respiratory failure, shock, neurological injury, and postoperative complications. [1–2] Respiratory failure in pediatric patients may be present as hypoxemic (low PaO_2) or hypercapnic (elevated $PaCO_2$), each requiring distinct ventilatory strategies.[1] Similarly, shock in children—particularly cardiogenic shock—often manifests differently than in adults, frequently presenting with hypotension and bradycardia due to age-dependent cardiovascular physiology.[2]

Unlike adults, children exhibit significant developmental differences that influence critical care management. These include anatomical variations in the airway (such as a relatively larger tongue and a more anterior larynx, with cricoid cartilage being the narrowest part in neonates and infants), differences in respiratory mechanics, heart rate–dependent cardiac output, and altered pharmacokinetics affecting drug distribution and metabolism. This is a vital point of airway management at this age group. The cricoid cartilage remains very important in neonates, infants and toddlers; because the edema there causes major resistance increase. This is up to 5-8 years of age. Then from 8-10 years increasingly through adolescent the glottis (rima glottidis) becomes the narrowest portion of the airway. The larynx is funnel shaped in early childhood. By adulthood, the airway becomes more cylindrical. There are many studies at this context and at recent years were done by measuring the muscle tones and other precise techniques.[3-4] Therefore, an appropriate size cuffed endotracheal tubes must be chosen to fit the larynx of different pediatric age groups. Moreover, the cuffed endotracheal tube is important in children where emergency operations are to be done such as appendicectomy whether open type on by laparoscopy, obstructed inguinal hernia repair. The other issue during the difficult operations of neonates for instance; pyloromyotomy in pyloric stenosis, Tracheoesophageal fistula excision and congenital diaphragmatic hernia closure. These age-specific characteristics necessitate tailored approaches to ventilation, hemodynamic support, and pharmacologic therapy in the PICU setting. Pressure-controlled ventilation is commonly preferred in neonates and infants to minimize barotrauma and optimize lung compliance.[2-3]

Neurological conditions also represent a significant proportion of the PICU admissions and include traumatic brain injury, stroke, and spinal cord injury, which may present with impaired consciousness, paraplegia, or hemiplegia. These conditions require precise neuroprotective strategies, including optimization of cerebral perfusion and oxygenation.[4]

Anesthesiologists have historically played a pivotal role in the evolution of critical care medicine. In the pediatric setting, their expertise in airway management, perioperative physiology, mechanical ventilation, and anesthetic pharmacology particularly at intensive care unit; when a child is admitted with status epilepticus, some drugs must be given only inside the RCU such as thiopentone (pentothal) that's a barbiturate drug which may cause apnea that necessitates endotracheal intubation and putting the child on ventilator. Moreover, other drugs such as the propofol which is an anticonvulsant agent also has the same implication may necessitates laryngeal tube insertion and artificial ventilation. The pediatrician sometimes needs to add other drugs to stop the convulsive fit like Levetiracetam (Keppra), Sodium valproate and at other times Carbamazepine (Tegretol) or Pentobarbitone (Luminal) or even midazolam infusion pump. all these anti-epileptic drugs can be used at refractory epilepsy of children at their admission to intensive care unit. As a results anesthesiologists have an essential role and vital members of the PICU team. Furthermore, anesthesiologist ability to integrate intraoperative and postoperative care ensures continuity of management and contributes to improved patient outcomes. This narrative review examines the role of Anesthesiologists in the PICU, focusing on clinical responsibilities, evidence-based practice, and future directions.[5]

2. Core Roles of Anesthesiologist in the PICU

2.1 Airway Management in the PICU

Airway-related complications remain a major source of morbidity in critically ill children.[6] Pediatric Anesthesiologists possess advanced expertise in managing difficult airways, particularly those associated with congenital anomalies, craniofacial syndromes, and postoperative airway edema. Common conditions associated with difficult pediatric airway include craniofacial syndromes such as Apert syndrome, Treacher Collins syndrome, Pierre Robin sequence, Nager syndrome, Goldenhar syndrome, and Pfeiffer syndrome, as well as Down syndrome (Trisomy 21). Additional challenges arise in patients with cleft lip and palate, VACTERL association, achondroplasia, and macroglossia.[6-7]

Anatomical features such as a relatively large tongue, anterior larynx, short neck, and the cricoid cartilage as the narrowest airway segment in neonates and infants significantly increase the risk of airway difficulty. These factors necessitate careful airway planning and the use of advanced techniques. In the PICU, Anesthesiologists contribute to airway management through multiple key interventions. These include rapid sequence and controlled tracheal intubation, particularly in emergency situations, as well as the use of advanced airway devices such as video laryngoscopy and fiberoptic bronchoscopy. They also play a critical role in managing unplanned extubation and failed airway scenarios, including escalation to emergency surgical airway techniques when required. In addition, Anesthesiologists are involved in cricothyroidotomy, tracheostomy placement often by

utilizing ultrasound guidance to improve procedural safety.[7-8]

Evidence from major anesthesiology journals demonstrates that airway interventions led or supervised by pediatric Anesthesiologists are associated with reduced hypoxemic events and fewer airway-related complications. In certain clinical scenarios, such as cleft palate, nasotracheal intubation may be preferred over oral intubation to optimize surgical access and airway stability.[8]

2.2 Mechanical Ventilation and Respiratory Support

Mechanical ventilation in pediatric patients requires precise adjustment according to age, weight, and disease-specific lung mechanics. Unlike adults, children—especially neonates and infants—have limited respiratory reserve, higher oxygen consumption, and greater susceptibility to ventilator-induced lung injury. Therefore, ventilatory management must be individualized and physiologically driven.[9]

Pediatric Anesthesiologists are highly trained in ventilatory physiology and play a central role in implementing lung-protective strategies, particularly in pediatric acute respiratory distress syndrome (PARDS). These strategies include the use of low tidal volumes, optimal positive end-expiratory pressure (PEEP), and careful limitation of airway pressures to minimize barotrauma and volutrauma. The choice of ventilation mode varies according to age and clinical condition. In neonates, pressure-controlled ventilation is commonly preferred as it allows better control of peak airway pressures and reduces the risk of lung injury. In some cases, pressure support ventilation can be used in spontaneously breathing patients who do not require neuromuscular blockade. Additionally, neonates requiring full ventilatory control may need sedation and neuromuscular blockade, such as rocuronium infusion, to ensure ventilator synchrony. While, in older children, volume-controlled ventilation or volume support modes specifically used for those requiring deep sedation or muscle relaxation such as in myasthenia gravis, Guillain Barré Syndrome, severe pneumonia with Lung atelectasis (Lung collapse), strong epileptic fits, acute severe asthma in other word status asthmaticus; sedation regimens, including agents such as propofol and midazolam, are often necessary to facilitate ventilation and improve patient-ventilator interaction in critically ill children.[9-10]

Ventilatory strategies must also account for underlying pathology, including obstructive airway diseases (for example in asthma) and restrictive lung conditions (for example in asbestosis, pneumoconiosis, tuberculosis and interstitial lung diseases such as fibrosing alveolitis), each requiring different approaches to ventilation settings and timing. Evidence from pediatric critical care literature demonstrates that Anesthesiologist involvement in ventilatory management is associated with improved gas exchange, optimized ventilatory parameters, and reduced incidence of ventilator-induced lung injury (VILI). Their expertise in tailoring ventilation to individual patient physiology is essential for improving outcomes in critically ill pediatric patients.[10-11]

2.3 Hemodynamic Monitoring and Cardiovascular Support

Children admitted to the PICU commonly present with hemodynamic instability, including septic shock (often of bacterial origin; such as severe meningitis, severe urinary tract infection, severe pneumonia or massive bronchiolitis at young infants or severe bronchitis at older children), cardiogenic shock, and postoperative cardiovascular instability. In pediatric patients, cardiovascular physiology differs significantly from adults, as cardiac output is primarily heart rate–dependent. Consequently, hypotension accompanied by tachycardia in pediatrics might indicates impending cardiovascular collapse and requiring urgent intervention.[12] Cardiogenic shock in children may occur in conditions such as dilated cardiomyopathy or congenital heart disease and can be associated with arrhythmias, including atrial fibrillation and ventricular ectopic beats (for example, bigeminy). These disturbances further compromise cardiac output and tissue perfusion. Anesthesiologists play a central role in managing these conditions due to their expertise in pediatric cardiovascular physiology and invasive monitoring techniques. Continuous hemodynamic monitoring is essential and includes arterial cannulation for real-time, beat-to-beat blood pressure measurement and frequent blood gas analysis. In addition, central venous catheterization allows administration of vasoactive medications and facilitates assessment of intravascular volume status.[12-13]

Anesthesiologists' role includes the placement and interpretation of arterial and central venous lines, enabling accurate hemodynamic assessment and guiding therapy. Vasoactive drug titration is a key component of management, with agents such as epinephrine, norepinephrine, and dopamine used to support blood pressure and cardiac output. In specific clinical situations, vasodilators such as sodium nitroprusside and nitroglycerin (glyceryl trinitrate) may be used to manage hypertension or reduce afterload.[13] Other antihypertensive agents like phenoxybenzamine, phentolamine, prazosin and related agents like doxazosin and terazosin are highly important in management of pheochromocytoma (tumor of adrenal medulla). The surgical excision of this tumor in children can technically be performed at almost any pediatric age including infancy if its life threatening or causing severe catecholamine excess. Pheochromocytoma naturally is uncommon before age of 5 years. Most pediatric age cases occur between 6-14 years. The mean age is approximately 11-13 years. Factors that detect operation are; hemodynamic instability, tumor size and its location,

endocrine control, genetic syndrome association, ICU availability, pediatric surgeon expertise. The infants, toddlers and preschool children can undergo excision when the tumor causes; malignant hypertension, cardiomyopathy, arrhythmias, stroke risk and multi-system crisis. Even very young children may undergo excision after rapid stabilization if urgent operation is needed: when these conditions occur; uncontrolled hypertension, recurrent hypertensive crises, pulmonary edema, catecholamine cardiomyopathy, encephalopathy, intracranial hemorrhagic risk, severe arrhythmias, tumor rupture or bleeding. These children need pediatric ICU, arterial line, central venous access, continuous vasoactive infusions. At infants and young children, the surgery is difficult because of the tiny circulating blood volume, severe blood pressure fluctuating, difficult vascular access, high glucose instability and limited physiologic reserve.[14] Another vital point is the adequate preparation is more important than age, especially among patients with inadequate alpha blockade, hypovolemia and intraoperative hypertensive crisis. The modern management focuses on ICU stabilization, alpha blockage by (phenoxybenzamine, phentolamine and prazosin), fluid expansion, invasive monitoring. Experienced pediatric anesthetist is needed in this case.[14] Before excision of this tumor a stable child needs usually 7-14 days minimum alpha blockade. Open surgery is preferred when there are giant tumor, invasive tumor, extra-adrenal tumor, suspected malignancy, vascular invasion and severe adhesions. Moreover, post operative concern in pediatric includes profound hypotension, hypoglycemia, rebound hyperinsulinemia, arrhythmias and adrenal insufficiency (bilateral surgery). Thus, pediatric ICU is essential after operation for monitoring purpose. From the other hand, intra-operative ICU-relevant hemodynamic is vital during tumor manipulation, especially in the presence of massive catecholamine surges or severe hypertension or arrythmias. Common agents needed are nitroprusside, phentolamine, nicardipine, magnesium sulphate and esmolol. The appropriate time for postoperative ICU management after tumor removal was just after adrenal vein ligation or tumor excision.[13] The patient may develop suddenly profound vasodilation, hypovolemia, catecholamine withdrawal symptoms and refractory hypotension. Therefore, postoperatively, vasopressors are needed (norepinephrine, vasopressin and occasionally epinephrine) especially if the patient had prolonged alpha blockade, depleted intravascular volume, catecholamine cardiomyopathy. In such cases, avoiding ketamine in anesthesia as it can stimulate sympathetic discharge, as well as, avoiding beta blockers (for example; propranolol and metoprolol) before alpha blocker as it led to hypertensive catastrophe may be required depending on the underlying pathophysiology.[13-14]

In summary, the commonest ICU practical regime used for severe pheochromocytoma crisis was; applying arterial line and central venous pressure (CVP) line, giving the patient volume expander, nicardipine or nitroprusside infusion, adding phentolamine if severe catecholamine surges or magnesium sulphate as adjuvant, while giving esmolol should be restricted (only after alpha blockade is established) and lastly, after surgery anticipate hypotension, then vasopressor is required.[13-14]

Fluid management should follow a goal-directed approach, balancing adequate resuscitation with the risk of fluid overload. This is particularly important in patients with renal impairment or conditions associated with increased fluid sensitivity. Functional hemodynamic assessment is essential to evaluate fluid responsiveness and optimize therapy.[13]
Anesthesiologists are also involved in the management of structural and congenital cardiac conditions requiring intervention, including cardiac catheterization for patent ductus arteriosus (PDA), valvular lesions such as mitral stenosis or regurgitation, and coarctation of the aorta. Their expertise is crucial in both procedural and postoperative settings. In postoperative cardiac and major non-cardiac surgical patients, Anesthesiologist-led hemodynamic management improves cardiovascular stability and enables early detection of complications.[15]

2.4 Sedation, Analgesia, and Delirium Prevention
Adequate pain control and sedation are fundamental components of safe and effective care in the PICU. Anesthesiologists contribute significantly through their expertise in multimodal analgesia and age-appropriate sedation strategies tailored to pediatric physiology and disease severity.[16]

Pain management in critically ill children requires a multimodal approach combining opioid and non-opioid analgesics. Commonly used opioids include fentanyl and morphine, while non-opioid adjuncts such as paracetamol and ketamine are frequently utilized to enhance analgesia and reduce opioid requirements. Ketamine, in particular, provides both analgesic and sedative effects with relative preservation of airway reflexes, making it useful in selected clinical scenarios.[16-17]

Sedation strategies must be individualized based on the patient's neurological status, underlying condition, and need for mechanical ventilation.[17] Delirium in the pediatric intensive care unit represents a form of acute brain dysfunction and is associated with increased morbidity, prolonged mechanical ventilation, and longer ICU stay. Prevention and management strategies focus primarily on minimizing modifiable risk factors such as reduction of benzodiazepine use, particularly agents like lorazepam and midazolam, which have been strongly associated with the development of delirium. Instead, alternative sedative agents such as dexmedetomidine, ketamine, and propofol (in selected older children) are increasingly preferred due to their more favorable neurocognitive profiles. In addition to pharmacological

strategies, non-pharmacological measures—including sleep optimization, environmental control, early mobilization, and family engagement—play an essential role in delirium prevention and overall neurological recovery in critically ill children.[18-19]

Anesthesiologists also oversee the safe use of neuromuscular blocking agents when indicated, particularly in patients requiring controlled mechanical ventilation or with severe respiratory failure. Agents such as rocuronium may be administered via infusion. Reversal of neuromuscular blockade should be carefully managed, with neostigmine used as a general reversal agent and sugammadex (Bridion) as a specific agent for aminosteroid neuromuscular blockers such as rocuronium.[17]

Recent literature emphasizes the importance of opioid-sparing strategies and enhanced recovery approaches in critically ill pediatric patients, highlighting the role of Anesthesiologists in optimizing sedation practices and improving overall outcomes.[18-19]

2.5 Perioperative and Postoperative Critical Care

A significant proportion of admissions to the PICU occur following major surgery or trauma. These include congenital surgical conditions such as congenital diaphragmatic hernia and tracheoesophageal fistula, as well as children undergoing cardiac or non-cardiac procedures.[20] In some cases, children with underlying congenital heart disease—such as large atrial septal defects (ASD) or big ventricular septal defects (VSD)—may present for non-cardiac surgery, requiring careful perioperative planning and postoperative monitoring. Anesthesiologists play a crucial role in ensuring continuity of care by transferring detailed intraoperative information—such as airway management, hemodynamic trends, fluid balance, and anesthetic techniques—to the PICU team. This continuity enables a seamless transition from intraoperative to postoperative management and supports individualized patient care.[20-21]

This integrated approach allows for early anticipation of complications, including respiratory failure, hemodynamic instability, bleeding, and metabolic disturbances. Anesthesiologists also contribute to the optimization of postoperative ventilation strategies and analgesia, ensuring appropriate respiratory support and effective pain control tailored to the child's condition. Furthermore, their involvement facilitates early identification of surgical or anesthesia-related complications, allowing prompt intervention.[21]

In pediatric surgical populations, particularly those with complex congenital anomalies or cardiac conditions, Anesthesiologist-led perioperative management has been associated with improved clinical outcomes. These include reduced PICU length of stay, fewer postoperative complications, and enhanced recovery.[22]

Furthermore, regarding blood transfusion and its components, such as whole blood, packed red blood cells, fresh frozen plasma, platelet concentrates, factor VIII, or other clotting factors, the anesthesiologist should carefully assess whether these products are required during the operation or during the patient's stay in the PICU. This should be done together with careful consideration of any associated complications and their management if they occur. The complications of blood transfusion are numerous and require full knowledge of their prevention and treatment at the correct and immediate time.[23]

3. Leadership, Education, and Multidisciplinary Collaboration

Anesthesiologists are actively involved in leading quality improvement initiatives, including the implementation of evidence-based protocols aimed at optimizing patient outcomes. These initiatives often focus on key domains such as mechanical ventilation strategies, sedation practices, and sepsis management, where standardized protocols have been shown to reduce variability in care and improve clinical outcomes. Their leadership in protocol development ensures that the PICU practices remain aligned with current evidence and international guidelines.[24-25]

Education represents another core component of their role. Anesthesiologists contribute extensively to the training of residents, nurses, and allied healthcare professionals, promoting competency in airway management, hemodynamic monitoring, and critical care procedures. Simulation-based education and structured teaching programs, often led by Anesthesiologists, enhance clinical skills, improve team performance, and reduce medical errors in high-risk environments such as the PICU.[26] Teaching nurses, assistants, technicians of anesthesia and new anesthesia residents how to perform basic life support and advanced trauma life support for the management of cardiac arrest when it occurs intraoperatively or after operation in the ICU is a highly important task of the clever anesthetist.[27]

Multidisciplinary collaboration is essential for effective PICU care, and Anesthesiologists frequently act as coordinators within the care team. They facilitate communication among surgeons, intensivists, nurses, and other specialists, ensuring a cohesive approach to patient management. Their involvement is particularly important in complex cases requiring integration of surgical, medical, and critical care perspectives. In addition, Anesthesiologists play an important role in ethical decision-making an end-of-life care discussions, particularly in patients with severe, irreversible conditions such as multi-organ failure. Their participation in these discussions supports patient-centered care, aligns treatment goals with patient values, and ensures appropriate use of life-sustaining therapies.[28]

4. Challenges and Limitations

Despite the expanding role of Anesthesiologists in ICUs, several challenges and limitations continue to affect the optimal delivery of care. One of the major issues is the variability in ICU training and practice across different regions and healthcare systems, which leads to inconsistencies in clinical competencies and standards of care. Differences in training pathways, certification requirements, and resource availability can result in heterogeneous levels of expertise among Anesthesiologist-intensivists.[29-30]

Another significant challenge is workforce shortage, particularly in low- and middle-income countries, where the demand for critical care services often exceeds the availability of trained specialists. This shortage places increased workload and stress on existing staff, contributing to burnout and potentially compromising patient care.[30-31] Additionally, there is often role overlap between Anesthesiologists and other intensivists, including those trained in internal medicine or emergency medicine. While multidisciplinary collaboration is essential for effective ICU care, unclear role delineation may lead to inefficiencies, communication gaps, or conflicts in clinical decision-making if not properly structured within a team-based model.[29,32]

A key strategy to address these challenges is the development and standardization of structured critical care fellowship training programs within anesthesiology. Such programs enhance clinical competency, ensure uniform standards of practice, and improve the integration of anesthesiologists into ICU leadership roles. Strengthening education and certification pathways is essential to maximize the effectiveness of anesthesiology in critical care. Furthermore, healthcare systems must address disparities in access to the PICU resources, training opportunities, and technological support to ensure equitable delivery of critical care services globally. Addressing these challenges requires coordinated efforts at institutional, national, and international levels.[32-33]

5. CONCLUSION

Anesthesiologists play a vital and continuously expanding role in the PICU, extending far beyond their traditional responsibilities in the operating room. Their expertise in airway management, mechanical ventilation, hemodynamic stabilization, pharmacologic optimization, and perioperative care positions them as indispensable members of the critical care team. Through their comprehensive understanding of physiology and acute illness, Anesthesiologists contribute significantly to the management of critically ill patients across a wide spectrum of clinical scenarios.

Their involvement is particularly crucial in high-acuity and time-sensitive conditions, including major trauma (for example, road traffic accidents and falls from height), emergency surgical cases, and acute medical emergencies such as status asthmaticus and severe epileptic seizures. In these settings, their ability to rapidly assess, stabilize, and initiate appropriate interventions directly impacts patient survival and outcomes. Furthermore, Anesthesiologists contribute to improve the PICU outcomes through their leadership in perioperative continuity of care, implementation of evidence-based protocols, and coordination within multidisciplinary teams. Their role in integrating intraoperative data into postoperative critical care management ensures a seamless transition of care and reduces the risk of complications.

As critical care medicine continues to evolve, the integration of Anesthesiologists into the PICU leadership, clinical practice, and system-level decision-making will remain essential. Strengthening training programs, expanding their role in critical care delivery, and enhancing interdisciplinary collaboration are key factors in optimizing patient outcomes and advancing the quality of the PICU care.

In conclusion, Anesthesiologists are not only procedural specialists but also comprehensive critical care physicians whose expertise is fundamental to modern PICU practice, particularly in complex surgical, trauma, and emergency settings.

Conflict of intertest

The authors of this study report no conflicts of interest.

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