

# Anesthetic Management of the Neonate having Emergency Surgery

Gavin F Fine Cook Children's Hospital, Fort Worth, Texas

**Objectives:** To understand the basic anatomical and physiological change that occur in the neonatal period that may affect anesthetic management. Understand the problems associated with medication administration especially opioids. To understand the management: of common neonatal emergencies and the associated risks of each disease.

**Introduction:** Advances in perinatology of the last several decades, have significantly improved the survival of critical ill newborns, including those born with extreme prematurity or other congenital anomalies. Many disorders once considered neonatal emergencies no longer require immediate surgical intervention, due to advancements of new technology and methods in treating critically ill neonates. The newborn requires anesthesia to maintain physiologic homeostasis, prevent pain, stress responses, and their sequelae. Because anesthesia-related morbidity and mortality are higher in infants,<sup>1,2</sup> especially when anesthesia is delivered by non-pediatric anesthesiologists,<sup>3</sup> Anesthesiologists need to have an understanding of the physiological, anatomical and pharmacological responses of these fragile patients to stress, including pain.<sup>1</sup> Neonatal emergencies may be divided by system into airway, abdominal, neurological and cardiovascular abnormalities. This review will focus on the management of the most common lesions associated with anomalies of gastrointestinal tract development and functional disorders seen in practice.

## **Review of basic anatomy and physiology of the neonate**

**Airway:** The anatomy of the upper airway is significantly different in the neonate compared to adults. Unlike adults, the larynx is at the level of the second and third cervical vertebrae and resulting in a more anterior appearance. The relatively large occiput in the neonate results in a natural sniffing position and excess neck extension may interfere with good visualization of the larynx. The epiglottis is omega shaped and lies at a 45°, obscuring the view of the vocal cords if not using an appropriately sized straight laryngoscope blade (Miller 0 or 1). The cricoid cartilage anatomically, is the narrowest part of the airway. An appropriate sized endotracheal tube (ETT) should allow for a leak of between 15-25 cmH<sub>2</sub>O to avoid airway complications. A size 3.5 mm ID ETT is usually appropriate for full term neonates, with 2.5-3 is used for smaller or premature infants. Approximate depth for ETT placement in the neonate is 7cm for 1 kg neonate with 1cm increase in depth with each kg increase in weight.

**Respiratory:** Newborns are obligate nasal breathers. Although respiratory mechanics are similar to the older patients, minute ventilation (respiratory rate) is 3-4 times the adult primarily because oxygen consumption is so much greater. Thus, MV:FRC ratio is 1-1.5:1 in newborns vs. 4-5:1 in adults (shorter time constant). Infants operate close to closing volume during tidal breathing,<sup>4</sup> resulting in more rapid anesthetic gas uptake and more rapid desaturation during apnea. Neonates respond paradoxically to hypoxia a short period of hyperventilation followed by apnea.<sup>5</sup> The immaturity of brainstem respiratory control mechanism and increased sensitivity to the respiratory depressant effects of anesthetics, sedatives and analgesics, combined with increased work of breathing and easy fatigability of the diaphragm, increases the risk of life-threatening hypoventilation or apnea during spontaneous ventilation during and after anesthesia .

**Cardiovascular:** during fetal life, low flow and high vascular resistance mark the pulmonary circulation. At birth the systemic vascular resistance rises due to elimination of the placental circuit via the ductus venosus, and the pulmonary vascular resistance falls as the infant the lung expands with the onset of respiration resulting in closure of the ductus arteriosus and foramen

ovale and onset of normal circulation. Pain, hypothermia, hypoxemia, hypercarbia, acidosis, N<sub>2</sub>O, high inflating pulmonary pressures result in increased pulmonary vascular resistance and may result in the return of fetal circulation leading to life threatening hypoxia and right sided heart failure. Systemic vascular resistance (SVR) is relatively fixed in infants at birth due to incomplete sympathetic innervation, that matures as the infant gets older,<sup>6</sup> resulting in the large arteries being in a relatively dilated state and unable to fully contract in response to hypovolaemia. Maintenance of blood pressure is therefore related to maintenance of cardiac output via heart rate, as the neonatal ventricles is relatively stiff with a fixed stroke volume because it has 50% of the contractile tissue present in adult ventricles.<sup>7</sup> Volume replacement (preload) and maintenance of heart rate are essential to maintenance of blood pressure in newborns.

**Neurological:** Immaturity of the brain and its blood vessels, especially in the preterm neonate with immature subependymal blood vessels, increases the risk of intraventricular hemorrhage (IVH) in the neonatal period. Factors, which increase the risk of IVH, include fluctuations of blood pressure, hypoxia, hypercarbia, low or high hemoglobin, and pain. The first 72 hours of life is the time of highest risk for IVH, however, the peri-anesthetic period does not appear to result in progression of IVH<sup>8</sup>. Questions have been raised about the vulnerability of the developing neonatal brain to injury due to anesthetic and/or analgesic agents such as isoflurane, nitrous oxide, ketamine and midazolam.<sup>9</sup> Currently, there is no evidence of such risk in humans.

**Pain:** Although formerly suspected of having blunted, immature response to pain, it is now clear that premature and full term newborns have the neuro-anatomic and physiologic, hormonal, and metabolic markers of the stress response.<sup>10, 11</sup> Inadequate management of pain may result in limited but important neurobiological differences on the response to future surgical procedures that many of these infants undergo.<sup>12</sup>

#### **Review of Pharmacology:**

The pharmacokinetic differences in neonates are primarily related to body fluid composition and renal and hepatic function. Differences in pharmacodynamics are related to differences in the end organ response. These differences impact choices and doses of medications in the perioperative period.

Body water (BW) comprises 90-105% of newborn's weight of which the extracellular fluid represents 50%. This combined with less protein results in an increased volume of distribution for water-soluble drugs. Renal and hepatic function is immature. Immature tubular function results in decreased clearance of some drugs, especially morphine and its active metabolite M6G.<sup>13</sup> Immature liver function results in decreased biotransformation of many drugs (e.g. opioids/local anesthetics) by the cytochrome P450 and other enzyme systems. Other factors affecting drug metabolism include cardiac function, protein binding, and factors affecting liver and kidney blood flow.

**Opioids:** The immaturity of the blood-brain barrier results in higher CSF opioid levels in newborns.<sup>14</sup> Additionally, immaturity of respiratory control mechanisms result in greater respiratory depression in newborns lower levels of these drugs,<sup>15</sup> predisposing the neonate to postoperative apnea. Remifentanyl, an ultra-short acting opioid, is metabolized by plasma esterases, resulting in a predictable half-life (10 min) regardless of age.<sup>16</sup> It is useful for its volatile sparing effects and for neonates at risk for postoperative apnea who one wants to extubate after surgery.<sup>17</sup>

**Muscle relaxants:** Neuromuscular transmission is immature at birth. The increased volume of distribution results in lower concentrations on non-depolarizing muscle relaxants at the neuromuscular junction, however, neonatal neuromuscular-receptors are more sensitive so there is no difference in initial dosage; 2<sup>nd</sup> doses, however, need to be reduced. Duration of muscle relaxation is extremely variable especially those that are steroidal based,<sup>18</sup> whereas, benzylisoquinoline muscle relaxants have a more predictable duration of action, providing the patient is normothermic and has a normal acid-base status.<sup>19</sup> Volume of distribution the greatest impact on the effect of succinylcholine; newborns require doses of 2mg/kg.<sup>20</sup>

**Local anesthetics:** The use of bupivacaine, the drug most commonly used for caudal epidural anesthesia, is associated with higher blood levels in neonates, due to immature liver metabolism and decreased protein binding. Blood levels may continue to rise greater than 48 hrs of administration.<sup>21</sup> As lidocaine is not as protein bound as, bupivacaine, but there is risk of toxicity due to low albumin and  $\alpha_1$ -acid glycoprotein levels in the newborn's blood.<sup>22</sup> Lidocaine may prove safer, especially since blood levels of lidocaine are more easily determined. Chloroprocaine, an amino ester, is metabolized by plasma esterases, and may be used with greater safety in newborns.

**Inhalation agents:** All inhalation agents have been used in neonates. Neonates have a higher rate of uptake of inhalational anesthetic agents due to their high cardiac output and increased minute ventilation. Because of difference in solubility and blood proteins, they attain a higher FA/FI ration than adults. MAC is lower in neonates than in older infants. Sevoflurane has less effect on infant hemodynamics, compared to halothane<sup>23</sup> and may be preferred to halothane. Time to emergence is significantly faster with desflurane than any of the other volatile anesthetic agents,<sup>24</sup> this may be particularly beneficial in the neonate in whom extubation is planned.

**Intravenous agents:** Thiopental is highly protein bound, resulting in higher free (i.e. effective) drug levels for any given dose, however, the larger volume of distribution results in higher induction doses (5-6 mg/kg) being used in neonates.<sup>25</sup> Propofol has been studied in infants, however little is know about its use in neonates. Propofol causes moderate to severe hypotension and hypoxia when used as an induction agent in doses of 2-3mg/kg. This may be due to preference for decrease in SVR as opposed to PVR. Although not an induction agent, dexmedetomidine is extremely useful if one wishes to keep a patient sedated and spontaneously breathing in order to perform an "awake" intubation. Decreases in blood pressure and heart rate do occur over time.<sup>26</sup>

**Postoperative apnea:** Risk of postanesthetic apnea (PAA) should be considered in all patients <44 weeks post conceptual age (PCA) regardless of the anesthetic technique. This risk persists until 60 weeks (PCA) for infants born less than 37wk PCA.<sup>27</sup> This is most likely due to immaturity of neural and chemical control and is extremely sensitive to anesthetic agents. PAA in small preterm infant involves central mechanisms as well as the upper airways. In larger preterm and term infants it is predominantly central in nature. Periodic breathing, which may be pronounced during emergence from anesthesia, is common in full tem neonates. Increased risk for PAA include younger gestational and PCA, history of apnea events, hemoglobin <10gm/dL<sup>27</sup> opioid administration, coexisting disease and physiologic abnormalities. Spinal anesthesia in the absence of any other anesthetics/sedatives/analgesics may decrease the risk of postoperative apnea in the former premature infant.<sup>28</sup>

### **General intraoperative management**

**Thermoregulation:** Neonates easily become hypothermic in the operating room (and during transport) due to their high body surface area to weight ratio, thin skin, decreased body fat, and inability to shiver. Anesthetics further impair non-shivering thermogenesis from brown fat, which is the newborn's only mechanism to maintain body heat. The consequences of hypothermia include pulmonary hypertension, delayed drug metabolism, hypoxia, and apnea. Heat is lost by evaporation, radiation, conduction, and convection. Strategies to maintain body temperature include increasing the temperature in the operating room to 80°F to prevent loss by radiation, using forced air warming, plastic drapes and overhead radiant warmers. Additional modalities include heated airway humidification and fluid warmers.

**Monitoring:** Minimal monitoring includes precordial stethoscope, pulse oximetry, capnography, NIBP, ECG and core temperature. The pulse oximeter should be placed on a preductal site. A second oximeter probe may be placed for back up, or when right to left shunting may be a possibility. Monitoring of urine output is advised in infants having major surgery. Intraarterial catheters are useful in critically ill neonates who are at risk for large intraoperative blood and/or fluid losses and who are hemodynamically unstable. It allows for continuous monitoring of

blood pressure and periodic assessment of blood gases, glucose, electrolytes including ionized calcium, hemoglobin and base deficit. CVP catheters are usually placed in the right IJ and are useful for both monitoring and as a secure IV access, particularly in procedures with anticipated large blood losses or fluid shifts. It should be remembered that there is significant risk associated with CVP catheters and PICC lines although not able to measure CVP are useful especially for administration of medication.

**Fluids, electrolytes and glucose management:** The immature kidney has diminished ability to handle a solute load. Newborns are born with excess sodium and require none in the first 72 hours of life. Maintenance fluid consists of hypotonic glucose solutions (D5 or D10 in either water or 0.2NS). For replacement of insensible and small volume blood loss, isotonic fluid should be administered separately. To prevent excessive fluid administration it is wise to run both maintenance fluids (4mL/kg/hr) on infusion pumps and operative fluid replacement should be administered by syringe bolus or by pump. Perioperative hyperglycemia can occur easily when high glucose containing fluids are given in combination with operative stress. Hyperglycemia (glucose >175 mg/dL) has been associated with increased morbidity in premature infants with necrotizing enterocolitis<sup>29</sup> and may worsen the outcome of IVH. During neonatal surgery, glucose administration should continue, but blood glucose measurement should be performed at frequent intervals to avoid both hyper- and hypoglycemia. Hypoglycemia is defined as blood glucose below 45mg/dL (1<sup>st</sup> 3 days of life, 60 mg/dL thereafter). In all emergency neonatal surgical cases, blood glucose should be checked regularly. Increased incidence of hypoglycemia is seen in infants born to diabetic mothers, those that are premature or small for gestational age, and infants that have been resuscitated.

**Regional anesthesia:** Caudal epidural anesthesia has become a most valuable adjunct to general anesthesia for newborn surgery. It eliminates the need for opioid administration, which decreases the risk of postoperative apnea, reduces the need for postoperative ventilation<sup>30</sup> and ameliorates the stress response.<sup>31</sup> Epidural catheters analgesia is most effective when the tip of the catheter is placed at the center of the dermatomes affected by the surgery. Advancement of the catheter from the sacral hiatus can be facilitated using a stylet catheter and the tip can be located during advancement using the electrical stimulation or the electrocardiographic method of Tsui.<sup>32</sup> If these techniques are unavailable, a “baby-gram” x-ray may be after the injection of 0.5ml of contrast to locate the tip of the catheter. A bolus of 1.5 – 2.0 mg/kg of bupivacaine (0.6 – 0.8ml/kg of 0.25% bupivacaine) followed by a continuous infusion of 0.2 mg/kg/hr is safe. Alternatively, Chloroprocaine (10-15 mg/kg) may be used with the least risk of toxicity. Caudal anesthesia should not be performed in patients at risk for coagulopathy and sepsis.

**Extubation:** Immediate postoperative extubation in the neonate requires that the patient be awake with a normal airway, full strength (hip flexion, arms lifting), normal vital signs including hemodynamic and respiratory stability and normothermic.

**Abdominal surgery:** Abdominal emergencies occur in 1 in 1500 live births. Despite having no feeding since birth, most newborn abdominal surgical emergencies are “full stomachs” and require volume loading (10-20mL/kg RL) and preoxygenation (1 min) prior to induction. An orogastric tube should be placed, suctioned and removed to decompress the stomach prior to induction. Airway control is achieved either via a rapid sequence intubation or an awake intubation. Awake intubations should only be attempted in those patients with a difficult airway or in patients where the risk of gastric insufflation will significantly affect the patients well being, as the stress from intubation may also increase the risk of an IVH.<sup>33</sup> Patients who are hemodynamically stable and not septic may have a caudal catheter placed to help decrease the duration of mechanical ventilation or if extubation is anticipated at the end of surgery.<sup>30</sup> N<sub>2</sub>O should be avoid in all cases of abdominal surgery to reduce insufflation of the stomach and intestines.

**GI tract conditions directly involving the respiratory tract**

**Tracheoesophageal fistula/Esophageal atresia.** TEF is characterized as type A-E, type C being the most common. It is most commonly diagnosed in the delivery room when a suction catheter cannot be passed from the mouth into the stomach due to the esophageal atresia. 20-30% of infants with TEF are premature and there is a high incidence other congenital anomalies. Birth weight <1500g and cardiac anomalies (especially ductal-dependent lesions) are good predictors of morbidity and mortality.<sup>34</sup> All infants with TEF should have an echocardiogram. CXR should be performed. The side of the aortic arch should be identified, as the surgical incision should be made on the opposite side. Surgery should be delayed until the workup is completed. Infants have pooling of secretions in the pouch and should be kept in a semi-upright position with a drainage catheter on low suction in the pouch. Gastric contents can also enter the lungs through the fistula. IV access should be established prior to induction. The pouch should be aspirated prior to induction. Spontaneous ventilation during induction is preferred to prevent gastric distention. The infant is intubated deep without muscle relaxant and with gentle PPV, listening over the lungs and the stomach identifies the location of the fistula. The ETT is taped at a location just below the fistula. If the fistula is at the carina, the ETT may be advanced into the bronchus of the lung on the non-operative side. Many surgeons will do a rigid bronchoscopy after induction to locate the fistula. If ventilation can be accomplished without gastric inflation, the patient can receive muscle relaxant. A caudal catheter may be advanced to T6-T7, to supplement the general anesthesia, and provides excellent postoperative analgesia without the use of opioids, this may facilitate extubation. Infants smaller than 1500g, may require postoperative mechanical ventilation. There is debate whether the risk of reintubation is greater in these infants than the risk of continued intubation with respect to the site of the fistula.

**Congenital Diaphragmatic hernia:** Most CDH is diagnosed in the prenatal period. Although fetal surgery (both primary repair and tracheal ligation) has been tried these techniques have been abandoned.<sup>35</sup> Improved ventilation techniques include high-frequency ventilation and ECMO. Also new trends favor the use of nitric oxide and pulmonary vasodilators, however, the use of NO is controversial.<sup>36</sup> Morbidity and mortality continues to remain high despite modern therapy. A poor outcome is associated with polymalformation, abnormal karyotype and prematurity as opposed to isolated CDH.<sup>37</sup> Other factors predicting poor prognosis are PaO<sub>2</sub> <80mmHg or PCO<sub>2</sub> > 40 mmHg after therapy. Time should be taken to stabilize these patients prior to coming to the OR. This may take up to 10 days if severe pulmonary hypertension. In the OR care must be taken not to use high volumes or ventilation pressure as this will trauma to the good lung. Even the “good” lung has some degree of mild hypoplasia.<sup>38</sup> Intra-arterial catheterization is recommended for routine blood gas analysis. N<sub>2</sub>O should be avoided.

### **Functional/pseudo obstruction**

**Intestinal atresia/bowel obstruction:** Duodenal atresia usually presents with bilious vomiting without abdominal distension shortly after birth. It is associated with annular pancreas, vertebral defects, congenital cardiac lesions, esophageal atresia and up to 60% of patients with duodenal atresia have trisomy 21.<sup>39</sup> Jejeunal/ileal atresia presents later than duodenal atresia with bilious vomiting and/or signs of abdominal distention/ileus. One should always consider cystic fibrosis or Hirschprung’s disease with midgut atresia (<sup>40</sup> Patients should be examined for signs of dehydration and electrolyte imbalances and these should be corrected prior to surgery.

**Malrotation/midgut volvulus:** This condition results with failure of rotation and fixation of the intestines on return from the physiologic hernia into the abdominal cavity (10<sup>th</sup> week of intrauterine life). It is a true surgical emergency as the bowel can be ischemic due to interruption of blood flow resulting in necrosis and/or perforation with associated sepsis and coagulopathy. It is often missed immediately after birth as meconium is passed and the abdomen is scaphoid. Rapid physical and laboratory assessment with fluid resuscitation of 20 ml/kg of isotonic crystalloid should be performed prior to rapid sequence induction. Derotating the bowel may cause vasoactive mediator release that may cause acidosis and hypotension. Invasive monitoring

is recommended in septic unstable patients for monitoring of blood pressure, acid-base status and glucose. Inotrope support is often needed in severe cases.

**Meconium Ileus:** This condition is often treated medically. If this fails surgical manipulation of the meconium plug might be required. It is most often associated with cystic fibrosis.

**Hirschprung's Disease:** This disease often has a delayed presentation. The pathology is aganglionosis of the intestine. Diagnosis is by rectal biopsy. Initial treatment is conservative. These neonates are usually healthy.

### **Abnormalities of abdominal wall development**

**Omphalocele/gastroschisis.** Gastroschisis is a full thickness defect of the abdominal wall usually to the right of the umbilicus, whereas omphaloceles are usually covered by a three-layer membrane (peritoneum, Wharton's jelly, amnion). Unlike gastroschisis, omphalocele is often associated with other anomalies and a full work up including cardiac and neurological should take place prior to proceeding with anesthesia. Long term prognosis is associated with the degree of bowel damage in gastroschisis as opposed to associated anomalies with omphalocele.<sup>41</sup> Primary closure is unlikely for moderate to large defects and should be abandoned if measurement of intragastric or visceral pressure is  $> 20$  cm H<sub>2</sub>O, if peak airway pressure increases, and if central venous pressure increases by more than 4 cm H<sub>2</sub>O.<sup>42</sup> These changes predict compromise in visceral blood flow (kidney and gut) and ventilation. A staged approach to closure, with a silo with a spring ring, is now often used. This procedure may be performed at the bedside in unstable neonates. These patients are full stomachs. The increased intra-abdominal pressure and diaphragmatic elevation reduces respiratory compliance, extubation is inadvisable and any anesthetic technique including a high narcotic technique can be used. A pulse oximeter probe should be placed on the foot in addition to the hand as too tight abdominal wall closure can result in compromised blood flow, which will be seen by a change in pulse wave form. Metabolism of drugs dependent on hepatic metabolism may be decreased if the intra-abdominal pressure is too high. In gastroschisis or ruptured omphalocele there is large insensible fluid loss from the large area of irritated bowel exposed, requiring large amounts of isotonic crystalloid ( $>10$  ml/kg/hr) or colloid to maintain blood pressure. Rarely dopamine infusion may be necessary especially on those patients with associated anomalies.

### **Conditions causing peritonitis**

**Necrotizing enterocolitis (NEC):** NEC is a condition that primarily affects premature infants. It occurs a result of bowel ischemia and may be caused by hypoxia, hypoperfusion, feeding, medical interventions (indomethacin/transfusion), and/or infection. There are no pathognomonic features and most infants present with sepsis and physiologic instability. The classical sign of pneumatosis intestinalis may be absent. Frequently the condition progresses to feeding intolerance, abdominal distention, acidosis, bleeding and coagulopathy.<sup>43</sup> Most NEC is managed conservatively with antibiotics and cessation of feeding. If conservative management fails, these neonates come to the operating room often intubated and on inotropic support (usually dopamine). Large volumes of crystalloid and colloid including transfusion of blood and blood products are often required. Placement of an abdominal drain percutaneously in the NICU with local anesthetic and sedation often results in improvement and may avert the need for a laparotomy.<sup>44</sup>

### **Miscellaneous**

**Pyloric Stenosis:** Pyloric stenosis presents usually 2-6 weeks of age with repeated projectile non-bilious vomiting resulting in hypochloremic dehydration. Diagnosis is confirmed by ultrasound. Prior to surgery, measurement of electrolytes and correction of hypovolemia and alkalosis should be accomplished by administration of 10-20 ml/kg isotonic fluid, with the goal being to lower the serum HCO<sub>3</sub> to  $<30$  mEq/L. Maintenance fluid of D5 0.45NS at 4 ml/kg/hr should be administered concomitantly. Although alkalosis is usually associated with hyperkalemia, 36% of patients with PS present with hyperkalemia. If there is no gastric tube present, one should be placed and suctioned (after administration of 0.15 mg atropine) with the

infant turned from side to side to empty the stomach as fully as possible. Most people perform a rapid sequence induction. Maintenance of anesthesia is usually inhalation agent, although use of remifentanyl has been reported with good outcomes.<sup>45</sup> Patients have minimal discomfort postoperatively after wound infiltration and rectal acetaminophen. Opioids are not required. Postoperative oximetry and cardiorespiratory monitoring is essential.

**Inguinal Hernia:** Repair of inguinal hernia is frequent in the neonatal period, especially in ex-premature infants. Because of a high risk of incarceration in these infants, repair is frequently performed electively prior to discharge from the NICU, at postconceptual ages <60 weeks. Alternatively, infants may present with incarcerated inguinal hernia. Some of these infants may have residual chronic lung disease (CLD) with reactive airways and parenchymal damage. Evaluation of respiratory status (including oxygen saturation and medications) and hemoglobin are important. Infants of this PCA are often anemic, increasing the risk of postoperative apnea. When hernia repair is elective, inhalation or IV induction may be performed. Former premature infants who have had prolonged intubation and ventilation are at risk for subglottic narrowing stenosis that may be asymptomatic. Smaller tubes (2.5-3.0) should be available. Patients with incarcerated hernia require rapid sequence induction. In infants with CLD, care should be taken to ensure adequate depth of anesthesia for intubation as severe bronchospasm may occur with desaturation. Bronchospasm may also occur on emergence and may be ameliorated by intraoperative administration of albuterol through the ETT. Maintenance with inhalation agent and caudal administration of ropivacaine 0.2% obviates the need for opioids, but does not eliminate the risk of apnea. In a large series, the use of spinal anesthesia alone for elective repair of inguinal hernia in ex-premature infants has been shown to virtually eliminate the incidence of apnea. Caffeine (10mg/kg) administered slowly IV during surgery may decrease the risk of post-anesthetic apnea.<sup>46</sup>

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