REVIEW

Preoperative management of congenital diaphragmatic hernia: Texas Children's Hospital guidelines

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ABSTRACT

Congenital diaphragmatic hernia is a rare but potentially fatal condition in which abdominal organs herniate into the thoracic cavity, leading to pulmonary hypoplasia and respiratory distress. Inter-institutional variability exists for disease management, and in this study, we present evidence-based recommendations regarding delivery room management, respiratory, hemodynamic, and nutritional support, sedation, and vascular access. Adequate preoperative management is essential for stabilizing these neonates before surgical correction, aiming to improve pulmonary function and overall neonatal well-being. In the present manuscript, we detail the preoperative approach employed by Texas Children's Hospital to manage congenital diaphragmatic hernia.

Keywords: Newborn; Hernias, Diaphragmatic, Congenital; Respiration, Artificial; Hypertension, Pulmonary; Clinical Protocols; Practice Guideline (Source: MeSH)

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Manejo preoperatorio para la hernia diafragmática congénita: directrices del Texas Children's Hospital

RESUMEN

La hernia diafragmática congénita es una afección rara pero potencialmente mortal en la que los órganos abdominales se hernian en la cavidad torácica, lo que conduce a la hipoplasia pulmonar y la dificultad respiratoria. Existe variabilidad inter-institucional para el manejo, y en este documento presenta las recomendaciones, basadas en evidencia, respecto al manejo en sala de partos, soportes respiratorio, hemodinámico y nutricional, sedación, y acceso vascular. Un adecuado manejo preoperatorio es fundamental para estabilizar a estos neonatos antes de la corrección quirúrgica, con el objetivo de mejorar la función pulmonar y el bienestar neonatal en general. En este documento, se detalla el enfoque preoperatorio empleado por el Texas Children's Hospital para el manejo de la hernia diafragmática congénita.

Palabras clave: Recién Nacido; Hernias Diafragmáticas Congénitas; Respiración Artificial; Hipertensión Pulmonar; Protocolos Clínicos; Guía de Práctica Clínica (Fuente: DeCS)

INTRODUCTION

Congenital diaphragmatic hernia (CDH) is a complex clinical entity caused by a developmental defect of the diaphragm. Herniation of the abdominal viscera into the thorax causes pulmonary compression and interferes with normal lung development. The clinical manifestations are abnormal bronchial and pulmonary arterial development, with pulmonary and vascular hypoplasia, pulmonary arterial muscle hyperplasia, and consequent pulmonary hypertension (1).

Modern advances in technology and clinical practices for this disease have improved overall survival to 79%, fluctuating between 30-60% when there are no associated structural or chromosomal abnormalities, with isolated CDH having the highest survival rates (2-4). This

variability in CDH-related incidence and mortality, possibly due to a lack of standardized protocols, underscores the urgency of a comprehensive approach and specialized care to improve outcomes. Interdisciplinary collaboration between obstetricians, neonatologists, pediatric surgeons, and other health care professionals plays a crucial role in the prognosis of neonates affected by CDH (5). In this context, Texas Children's Hospital, an institution with a recognized track record at the forefront of pediatric surgery and management of CDH, has developed a set of preoperative guidelines.

This document aims to detail and share the evidence-based, preoperative approach employed by Texas Children's Hospital to manage moderate to severe CDH. Key aspects of delivery room stabilization, respiratory support, nutritional management, and potential complications clinicians should consider when managing infants with CDH before surgery are addressed. Through disseminating experience and evidence-based practices, the aim is to provide a framework that can be adapted and applied in other centers to optimize the care and surgical outcomes of neonates with this condition. It is intended that these guidelines will not only serve as a resource for the implementation of preoperative management strategies but will also foster an ongoing dialogue and constant improvement in the treatment of CDH worldwide.

METHOD

In this review, we critically reviewed the evidence on the management of CDH hernia in neonates. Eligibility criteria were those studies focused on neonates with a diagnosis of CDH. Articles were reviewed in the following search engines: PubMed, Cochrane Collaboration Database, and Google Scholar; this search was supported by the Texas Children's Hospital Evidence-Based Outcomes Center (TCH Evidence-Based Outcomes Center). For each intervention, a PICO question was asked (see supplementary material 1). Existing protocols, guidelines, and external clinical guidelines referenced in the text were also used.

RESULTS

Delivery room

At birth, endotracheal intubation is performed immediately to avoid bag ventilation to reduce risk and associated lung damage (6). A preductal pulse oximeter is placed, the stomach is decompressed with a nasogastric tube, to prevent stomach and intestinal distension and reducing pulmonary compression. The patient should be ventilated with a low peak inspiratory pressure (PIP) to minimize lung injury. At Texas Children's Hospital (TCH), PIP with a target <28 cm H2O is used. There are no specific studies for saturation and resuscitation targets in the delivery room, and ≥70 % is used for the first ten minutes after birth and >80 % for the first two hours of life.

Administration of exogenous surfactant in patients with CDH should not be routinely performed (7,8). However, patients who underwent Fetoscopic Endoluminal Tracheal Occlusion (FETO) may have a decrease in type II pneumocytes, leading to surfactant deficiency (9). Surfactant use may be considered in patients with CDH who have a history of FETO or those with preterm birth (<37 weeks gestation). However, this is a weak recommendation as the evidence is low quality.

In addition, during stabilization in the delivery room, peripheral IV and umbilical access are placed in the Intensive Care Unit (see Figure 1).

Ventilation and respiratory support

Ventilation strategies focus on maintaining adequate oxygenation and preventing barotrauma and volutrauma. High-frequency oscillatory ventilation (HFOV) is effective in some cases (10-12), although the superiority of high-frequency ventilation modes over conventional support has yet to be established (13-15). However, there is more clinical experience with conventional ventilation strategies that minimize the risk of barotrauma, as a result, it is suggested as the preferred method of ventilation in multiple guidelines (16-22).

In this context, clinicians should use the minimum parameters to maintain preductal oxygen saturation above 80% or preductal oxygen partial pressure (PaO2) above 40 mmHg. In turn, it is important to allow permissive hypercapnia, defined as a partial pressure of carbon dioxide [PaCO2] between 45 and <65 mmHg and arterial pH >7.25 to 7.4 (18,19,23).

Initial respiratory support for patients with CDH should be performed using a conventional ventilator in AC/VG (Assist Control/Volume guarantee) mode with initial settings of PEEP 5-6 cmH2O, tidal volume (TV) 4-5 mL/kg, rate of 40 breaths/min, inspiratory time (IT) 0.3 seconds, and an oxygen concentration (FiO2) adjusted to obtain preductal saturations ≥80 % (4,5,16,18,20-22). It is essential to emphasize that frequent blood gas monitoring is essential to adjust ventilator parameters, although this must consider adequate vascular access.

High Oscillatory Frequency Ventilation

As previously mentioned, patients with CDH generally undergo conventional gentle ventilation strategies. This approach tolerates permissive hypercapnia as long as PH is maintained above 7.25 and preductal oxygen saturation above 85%. However, in some patients, adequate gas exchange is not completed, and in these cases, clinicians should consider changing the ventilation mode to high-frequency oscillatory ventilation (HFOV). This switch is contemplated for those patients unable to achieve target PCO2 with conventional ventilation with PIP ≤ 28 (10,16,18,24). This is considered a "rescue" strategy (see Figure 2). Once transitioned to HFOV, the strategy is to increase Mean Airway Pressure (MAP) and amplitude (Delta P) to achieve the desired physiologic monitoring parameters.

Hemodynamic Support

Hemodynamic support is an essential aspect of postnatal care of the CDH patient to ensure adequate oxygen delivery to vital organs. Preferably, invasive blood pressure monitoring is

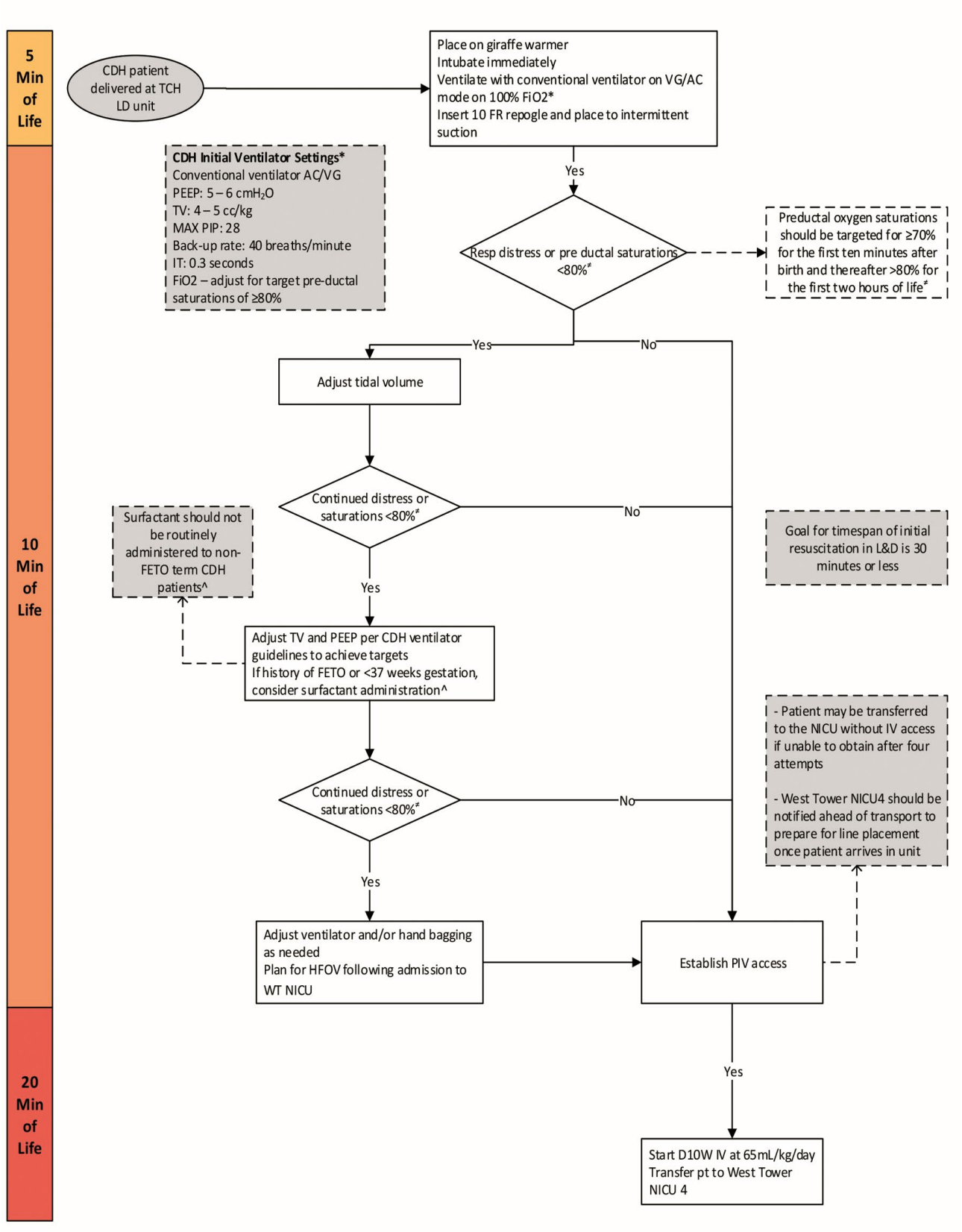


Figure 1. THC Evidence - Based Outcomes Center
Clinical algorithm for initial management of congenital diaphragmatic hernia patients labor and delivery algorithm

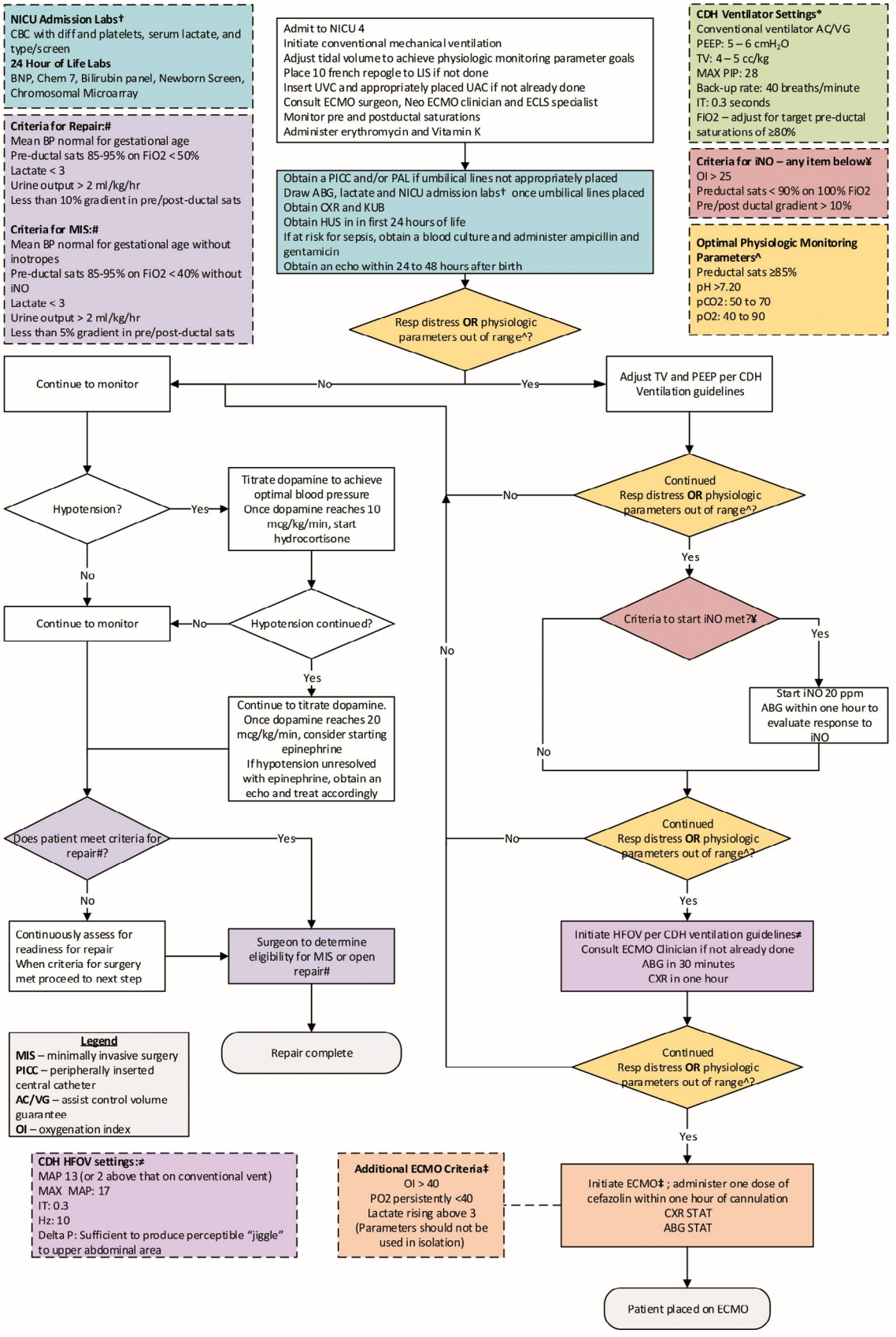


Figure 2. THC Evidence - Based Outcomes Center
Clinical algorithm for the acute management of congenital diaphragmatic hernia patiens prior to ECMO inpatient algorithm.

chosen over noninvasive monitoring. The goal is to maintain the mean arterial pressure (MAP) of patients with CDH, like that of other NICU patients, between 5-10 mm Hg above their gestational age (GA) (24). In addition, other clinical signs of adequate systemic blood pressure, such as a heart rate commensurate with GA, lactate below 3 mmol/L, urine output greater than 1 ml/kg/h, and average capillary refill time, should be monitored (25).

It is important to continue monitoring pre- and post-ductal saturations. If there is concern for inadequate perfusion, clinicians may consider volume resuscitation or vasoactive therapies upon clinical evaluation. It is unusual for newborn patients with CDH to require extensive volumetric resuscitation unless there is a perinatal concern for placental abruption, acute volume loss, or hemorrhage. A bolus of 5-10 ml/kg of isotonic solution or colloid blood product may be considered in such cases.

When a neonate presents with hypotension (MAP < EG), dopamine is initiated as the primary vasoactive medication (21,26,27). Once dopamine dose reach 10 mcg/kg/min, hydrocortisone is introduced at 1 mg/kg every 6 to 8 hours, below the stress dose. Hydrocortisone may be beneficial in cases of hypotension refractory to initial vasoactive medication (21,22,28).

If a dopamine dose of 20 mcg/kg/min is required, the second-line vasoactive medication in the institution is epinephrine. Other vasoactive medications are norepinephrine, vasopressin, dobutamine, and milrionone (21,22,29). In situations where further vasoactive support is needed, it may be helpful for the physician to consider performing an echocardiogram to assess left and right ventricular function, as well as the presence of a patent ductus arteriosus, which will aid in the selection of appropriate vasoactive medication and the quantification of hypertension (20-22,26,30).

Management of Pulmonary Hypertension

From a physiologic standpoint, pulmonary arterial vasodilation is essential at birth to facilitate the transition from fetal to neonatal circulation. However, patients with CDH often experience neonatal persistent pulmonary hypertension (PPHN) due to multiple factors, including pulmonary hypoplasia, pulmonary derecruitment, and vascular remodeling (1,31,32). Clinically, NPPH is one of the main determinants of morbidity and mortality in patients with CDH, as it can lead to shunting of the circulation, hypoxia, hypercapnia, and cardiac dysfunction (33).

In cases of severe PPHN, i.e., when associated with ventricular dysfunction and/or systemic hypotension, immediate administration of inotropic agents is required. The main objective is to maintain blood pressure in the upper limits of normal, which generally ranges between 45 and 55 mmHg, to minimize right-to-left shunting.

In patients with severe PPHN associated with significant right-to-left shunt, hypoxemia, oxygenation index (OI) greater than 25, as well as preductal saturations less than 85% despite FiO2 at 100%, or a gradient between preductal and postductal saturations ≥10%, treatment with a pulmonary vasodilator should be considered. Although the benefit of inhaled nitric oxide (iNO) in neonates with CDH has not been consistently demonstrated (16,34-36), this is the preferred initial agent in most cases (34,36-38) because of limited data and clinical experiences suggesting that it may prevent the need to require extracorporeal membrane oxygenation (ECMO) in some patients (37,39). Other pulmonary vasodilators such as phosphodiesterase type 5 inhibitors (e.g., sildenafil), prostacyclin analogs (e.g., treprostinil, iloprost), and endothelin receptor antagonists (e.g., bosentan) are occasionally used in patients with CDH to treat refractory or persistent PPHN but are not considered first-line agents.

In situations of respiratory instability and/or hemodynamic collapse that do not respond to optimal medical therapy, including ventilatory support, inotropic support, and iNO, referral or referral to a center that can provide ECMO should be considered (17,40,41). ECMO therapy is reserved for those patients in whom lung disease is considered potentially reversible. However, in practice, it is not always possible to predict the reversibility of lung disease (42), and it is offered to patients as long as there are no contraindications.

Also, indications for ECMO for patients with CDH include an oxygenation index (OI) greater than 40 on two separate measurements, persistent partial pressure of oxygen (PO2) less than 40 mmHg or sustained increase in lactate above 3.0mmol/L, mean airway pressure (MAP) at VAFO >17 cm H2O and pre-ductal saturation less than 85% with less than 7.15 (24).

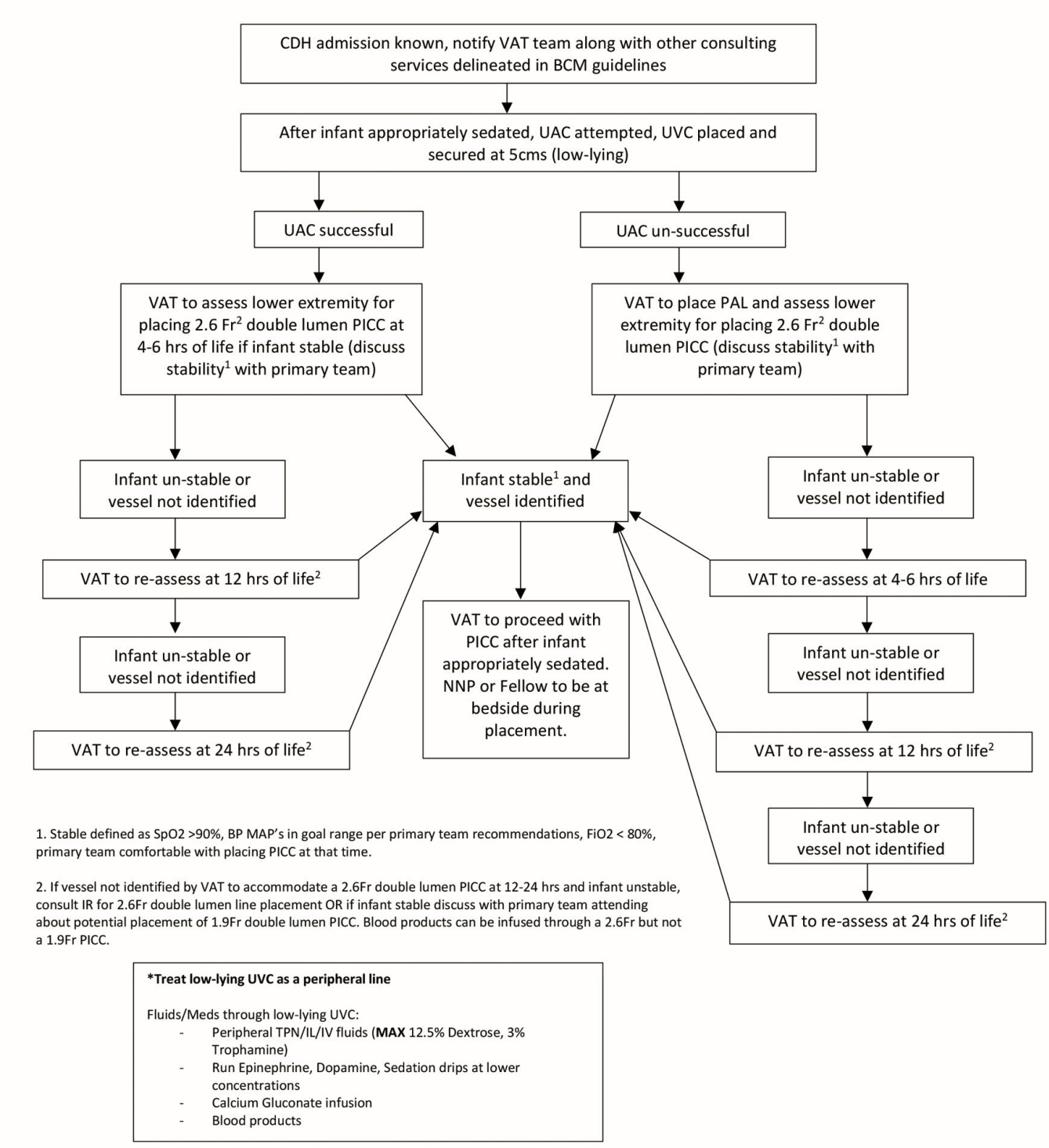
Sedation

Appropriate sedation is important to avoid significant agitation and/or desynchronization with the ventilator and to minimize PPHN. In some cases, it may be beneficial to allow the infant to retain a spontaneous contribution to minute ventilation; therefore, sedation should be carefully titrated to maintain spontaneous breathing (43). The agents of choice are morphine, and midazolam is introduced if necessary. Neuromuscular relaxants are used only when necessary, such as in case of significant desynchronization with the ventilator despite optimization of ventilator settings and sedation or when physiological stability cannot be achieved. Attention should be paid to the impact of sedative and narcotic agents as they may have a synergistic effect and cause arterial hypotension.

Vascular Access

The current consensus for managing CDH recommends establishing peripheral venous access in the delivery room. At the same time, elective or non-urgent procedures, such as umbilical line placement, should be performed once the patient is in the NICU. In patients with CDH requiring a central venous line, initial placement of an umbilical venous catheter (UC) and an umbilical arterial catheter (AUC) is suggested. When it is impossible to establish the umbilical venous catheter properly, a low-positioned umbilical venous catheter may be used temporarily until a suitable alternative is available (44). At Texas Children's Hospital, notify the vascular access team (VAT) in the event of failure to establish adequate umbilical access. This allows the placement of a

peripherally inserted central catheter (PICC) and a peripheral arterial line in patients whose umbilical access has not been established (see Figure 3). In patients with CDH requiring long-term vascular access, patients will also have a PICC placed once stabilized.



Note: Algorithm adapted from Fernandes and Pammi (24).

Figure 3. - Algorithm of line placement for admission of patients with Congenital Diaphragmatic Hernia

Nutritional Management

Patients with CDH should not receive enteral feedings until they have recovered from surgery and acceptable bowel motility has been established. This delay in initiating enteral feeding is necessary because of the possibility of mechanical obstruction and to avoid distention that could compromise pulmonary expansion. Following hernia repair, postoperative ileus, concern for mesenteric perfusion, and general physiologic instability must be considered. Therefore, providing adequate parenteral nutrition (PN) is essential, initiating it within the first 24 hours of life.

According to the American Society for Parenteral and Enteral Nutrition (ASPEN), guidelines for PN, a target of 2.5-3 gm/kg/day of lipid and protein is sought for term neonates (45). With these lipid and protein targets, it is possible to provide 100-110 kilocalories per kilogram per day (kcal/kg/day) to ensure adequate somatic growth. Furthermore, a retrospective review revealed that, for adequate growth, minimum protein requirements are ≥ 2.3 gm/kg/day (46,47).

Details on post-surgical nutrition will not be addressed in this installment. Initiation of enteral nutrition is expected until the patient has recovered from surgery and regained bowel function, evidenced by the presence of bowel sounds, non-bilious gastric output, and expulsion of gas and stool. Human milk is the preferred nutrition for all infants, including CDH patients.

Timing of surgical repair

Surgical repair of the diaphragm should be performed when the patient has reached physiologic stability (see Figure 2). In the unit, this physiologic stability is defined as mean arterial pressure within normal values for gestational age, preductal oxygen saturations in the range 85-95 % with an inspired oxygen concentration (FiO2) below 50 %, lactate levels below 3 mmol/L, diuresis above 2 mL/kg, and a preductal and postductal saturation gradient of less than 10 % (16,24,48,49). It is important to remember that in clinical situations, achieving these parameters is not always possible; for example, it is not always possible to reduce FiO2 below 50% and/or maintain optimal diuresis. Sometimes, the decision to proceed with surgical repair is based on increased lactate despite relatively mild pulmonary hypertension, especially in more minor CDH defects.

Overall, the medical team's focus should be on physiologic stability, considering pulmonary hypertension, preductal oxygen saturations, mean arterial pressure, and stable ventilation in the setting of a CDH, not requiring extracorporeal membrane oxygenation (ECMO). If ECMO is needed at the center, early surgical repair is preferred, and we aim to perform surgical correction within 48 hours. The timing of surgery is based on coagulation parameters, which can be very unstable in these patients.

Conclusion

This paper has detailed and shared the preoperative approach employed by Texas Children's Hospital to manage CDH. This review addresses key aspects, such as delivery room resuscitation, respiratory support, nutritional management, and potential complications clinicians should consider when managing infants with CDH in stabilization before surgery. The guidelines presented are based on evidence-based practices and accumulated experience at Texas Children's Hospital. By disseminating the experience and approach, the aim is to provide a framework that can be adapted and applied at other centers, aiming to optimize the care and surgical outcomes of neonates with this condition.

Ultimately, these guidelines serve as a resource for implementing preoperative management strategies and foster an ongoing dialogue and constant improvement in the treatment of CDH worldwide. Continued research and technological advances promise to improve the preoperative care of these neonates, contributing to a higher quality of life and improved outcomes for those affected by this complex medical condition.

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