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Decreased cerebral oxygen saturation during thoracoscopic repair of congenital diaphragmatic hernia and esophageal atresia in infants

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Abstract

Background/Purpose: Congenital diaphragmatic hernia (CDH) and esophageal atresia with tracheoesophageal fistula (EA/TOF) can be repaired thoracoscopically, but this may cause hypercapnia, acidosis, and reduced cerebral oxygenation. We evaluated the effect of thoracoscopy in infants on cerebral oxygen saturation (cSO_2), arterial blood gases, and carbon dioxide (CO_2) absorption.

Methods: Eight infants underwent thoracoscopy (6 CDH and 2 EA/TOF). Serial arterial blood gases were taken. Regional cSO_2 was measured using near-infrared spectroscopy. Absorption of insufflated CO_2 was calculated from exhaled $^{13}CO_2/^{12}CO_2$ ratio measured by mass spectrometry.

Results: CO_2 absorption increased during thoracoscopy with a maximum 29% ± 6% of exhaled CO_2 originating from the pneumothorax. $PaCO_2$ increased from 9.4 ± 1.3 kPa at the start to 12.4 ± 1.0 intraoperatively and then decreased to 7.6 ± 1.2 kPa at end of operation. Arterial pH decreased from 7.19 ± 0.04 at the start to 7.05 ± 0.04 intraoperatively and then recovered to 7.28 ± 0.06 at end of operation. Cerebral hemoglobin oxygen saturation decreased from 87% ± 4% at the start to 75% ± 5% at end of operation. This had not recovered by 12 (74% ± 4%) or 24 hours (73% ± 3%) postoperatively.

Conclusions: This preliminary study suggests that thoracoscopic repair of CDH and EA/TOF may be associated with acidosis and decreased cSO_2. The effects of these phenomena on future brain development are unknown.

Greater experience with minimally invasive techniques in infants and children has led to the use of thoracoscopy in neonates [1,2] for indications such as congenital diaphragmatic hernia (CDH) [3] and esophageal atresia with

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tracheoesophageal fistula (EA/TOF) [4]. Ventilation can be difficult for minimally invasive procedures, and during thoracoscopic procedures in neonates, the potential impact of carbon dioxide (CO_2) pneumothorax and collapse/reduced ventilation of the ipsilateral lung in an immature (and often pathological) neonatal cardiopulmonary system is a matter of great concern. Relatively few studies reporting on the cardiorespiratory consequences of thoracoscopy in neonates have been published [5-7], and most of these studies have relied on retrospective review of anesthetic charts. The advent of this new surgical procedure in such young children, given their cardiovascular and pulmonary specificities, requires a thorough evaluation of its tolerance [8].

Because of concerns about occurrence of acidosis during the thoracoscopic repair of both CDH and EA/TOF, we performed a prospective study to evaluate the effect of thoracoscopy with CO_2 pneumothorax on (1) arterial blood gases, (2) CO_2 absorption, and (3) cerebral oxygen saturation.

1. Methods

This was a prospective observational cohort study. Eight infants underwent thoracoscopy between March 2009 and March 2010 (6 CDH and 2 EA/TOF). Ethical approval (09/H0714/2) for this study and informed parental consent were obtained. Arterial blood gases were measured in all patients, preoperatively, intraoperatively, and postoperatively. Regional cerebral oxygen saturation (cSO_2) was measured in 6 infants using near-infrared spectroscopy (NIRS) with an in vivo optical spectroscopy oximeter (INVOS; Somanetics, Troy, Mich) via a cerebral neonatal sensor applied to the forehead. Measurements were taken preoperatively, intraoperatively, and 24 hours postoperatively.

Thoracoscopy was performed with both lungs ventilated. Patients were positioned semiprone. A 3- or 5-mm Hasson cannula was inserted through the third or fourth intercostal space in the posterior axillary line. The chest was insufflated to a pressure of 5 to 10 mm Hg using CO_2 at a flow rate of 1 to 4 L/min. Surgery was performed with the aid of 2 or 3 working ports. For repair of CDH, the hernia contents were reduced into the abdomen, and if a hernia sac was present, this was not resected. The defect was closed with interrupted nonabsorbable stitches. If necessary, a polyester patch (Bard Sauvage Filamentous Fabric; Bard, Billerica, Mass) was used to close the defect. When necessary, the posterolateral stitches were ligated extracorporeally using small skin incisions.

For patients with EA/TOF, the azygos vein was divided, the TOF was transfixed and ligated with a nonabsorbable suture, and the esophageal anastomosis was performed with several interrupted stitches.

Breath samples were collected at 15-minute intervals using a 10-mL syringe connected to a 3-way valve at the sampling line for measurement of end-tidal CO_2. The air was aspirated into a 10-mL syringe and immediately transferred into 10-mL vacuum test tubes (Labco, High Wycombe, UK) for the analysis [9]. Samples were collected before the start of the operation and every 15 minutes during pneumothorax. In addition, samples of medical CO_2 used for the pneumothorax were obtained for each operation.

1.1. Sample analysis

Breath CO_2 was analyzed for $^{13}CO_2/^{12}CO_2$ enrichment by gas chromatography as previously described[9]. Using the $^{13}CO_2/^{12}CO_2$ of the medical CO_2 used for insufflation to represent 100% of exhaled CO_2 originating from the pneumoperitoneum and baseline breath $^{13}CO_2/^{12}CO_2$ to represent 0%, the percentage of exhaled CO_2 originating from the pneumothorax at each time point was calculated as previously described [9]. Data are presented as mean ± SE (range), unless stated otherwise.

2. Results

There were 8 infants involved in this study (6 CDH and 2 EA/TOF). The diagnoses, ages, weights, and operative details of the infants undergoing thoracoscopy are shown in Table 1. The median weight was 2.9 kg (range 2.4-9.6 kg). Five were admitted as neonates, whereas 3 patients with CDH were older infants who presented with respiratory distress at 1, 3, and 7 months of age, respectively. One patient (number 4) with CDH required insertion of a patch. Median duration of operation was 87 minutes (range, 65-160 minutes) for thoracoscopic CDH repair and 162 minutes (range, 150-173 minutes) for thoracoscopic EA/TOF repair.

Analysis of $^{13}CO_2/^{12}CO_2$ enrichment in breath samples taken intraoperatively showed a progressive decrease in parts per thousand $^{13}CO_2$ during operation (Fig. 1A), suggesting absorption of medical CO_2. We calculated the percentage

Table 1 Patient demographics and operative details: diagnosis, age, and weight (at time of operation) of infants studied

Infant	Diagnosis	Age (d)	Weight (kg)	Conversion to open	Operating time (min)
1	CDH	8	2.8	Yes	135
2	CDH	7	2.4	No	65
3	CDH (late diagnosis)	36	3.9	No	80
4	CDH	4	2.5	Yes	93
5	CDH (late diagnosis)	102	5.9	Yes	75
6	CDH (late diagnosis)	314	9.6	No	160
7	EA/TOF	0	2.9	No	150
8	EA/TOF	1	2.9	No	173