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Comparison of Hypercarbia and Acidosis in Thoracoscopic and Open Approach Repair of Tracheoesophageal Fistula

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Introduction

The technique of tracheoesophageal repair has long since evolved from the first successful primary repair in 1949 to minimally invasive procedures in the last century [1]. While the surgical outcomes of the thoracoscopic technique seem comparable to the open approach, there persist concerns regarding the impact of the capnothorax on neonatal physiology during thoracoscopic repair [2]. We planned this observational study to help better understand the trend of hypercarbia and acidosis in neonates undergoing thoracoscopic tracheoesophageal repair and compare it to the open technique.

Materials and Methods

We planned a prospective observational study to assess the trend of hypercapnia and acidosis in the thoracoscopic and open repair of tracheoesophageal fistula. After obtaining institutional ethics committee approval, the study was registered with the clinical trial registry of India. Sixty-one neonates posted for tracheoesophageal repair were recruited over 18 months. We recruited term babies weighing more than 2 kg with type C TEF. Babies with pneumonia as detected by infiltrates on chest X-ray, congenital anomaly involving another organ system, those with cyanotic heart disease, and syndromic babies and those with long gap TEF not amenable to surgical repair were excluded.

Conduct of Anesthesia

After obtaining written informed consent from the parents/guardians, babies with TEF were recruited. Their baseline hemodynamic and respiratory parameters were noted. Before induction, suctioning of the upper esophageal pouch was done. After preoxygenation and induction, the main bronchus was deliberately intubated, and the ET tube was gradually withdrawn till bilateral air entry was present. Intravenous fentanyl was given for analgesia in the dose of 1 mcg/kg to 2 mcg/kg. Intraoperative heart rate, non-invasive blood pressure, oxygen saturation *via* plethysmograph and temperature were recorded every 5 min. Blood gas analysis was done 15 min after positioning the baby, at the time of fistula ligation and just before reversal. The decision for extubation was made based on the metabolic and hemodynamic profile of the baby. All children were shifted to the surgical neonatal intensive care unit for postoperative ventilation in the case of those who were not extubated. Blood gas analysis was recorded postoperatively 24 h post-surgery.

Surgical technique

Neonates were operated on either by conventional open thoracotomy technique or thoracoscopic technique. The concerned surgical team decided on the type of surgery. In the open approach, right posterolateral thoracotomy with extra pleural dissection was performed in a posterolateral position. In thoracoscopic technique, neonates were kept in a modified prone position with 30 to 45 degrees right side elevated. After insertion of the Veress needle in the 3rd or 4th intercostal space in the posterior axillary line, the chest was insufflated with CO_2 at the flow rate of 0.5 liter/min to 1 liter/min to maintain intrathoracic pressure of 4 mmHg to 6 mmHg. The surgical interventions were

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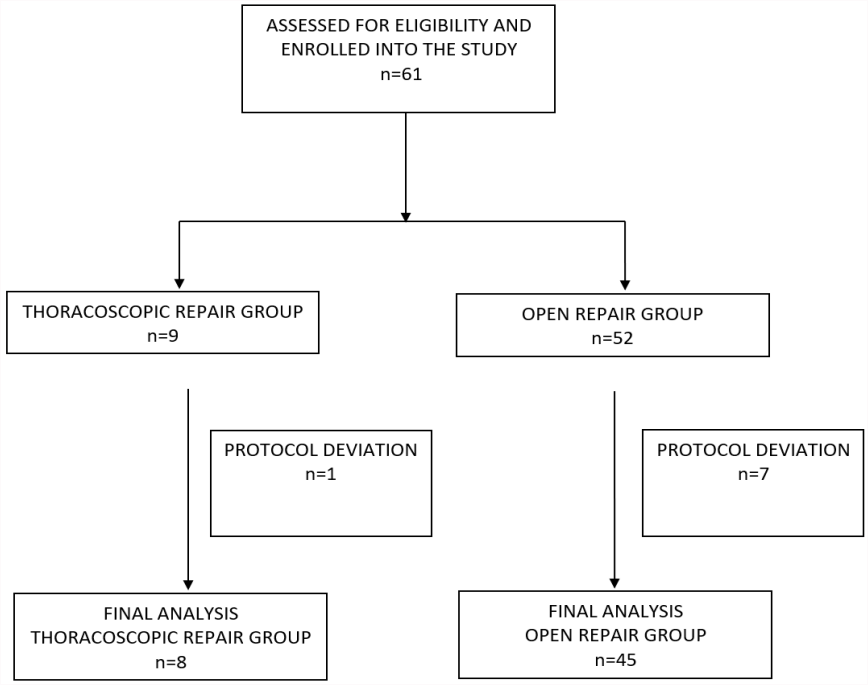

Figure 1: Consort diagram.

performed with 2 to 3 working ports. Both open and thoracoscopic procedures involved the mobilization of the upper and lower pouch of the esophagus after ligation of the fistula, followed by an end-to-end anastomosis. Intermittent cessation of capnothorax and lung retraction allowed lung recruitment when needed. A chest tube was placed at the end of the procedure. The cases where the procedure didn't go according to the plan, i.e., conversion to do esophagostomy/gastrostomy because of a large gap, were excluded from the study.

Statistical analysis

The cases were divided into Thoracoscopic Repair (TR) and Open Repair (OR) groups. Continuous data were presented as mean ± SD. The normality of quantitative data was checked by measures of Kolmogorov Smirnov tests of normality. Normally distributed data were analyzed using a student t-test. In our data, age was skewed, for which the Mann-Whitney test was applied. Qualitative or categorical variables were described as frequencies and proportions. Proportions were compared using Chi-square or Fisher's exact test, whichever was applicable. The correlation analysis of blood gases was done. Data regarding the manual ventilation duration, mechanical ventilation duration, ICU stay, were analyzed by independent t. A p-value of <0.05 was considered to indicate statistical significance. All calculations were performed using SPSS® version 17 (Statistical Packages for the Social Sciences, Chicago, IL).

Results

A total of sixty-one cases were enrolled for this study (Figure 1). Amongst these, nine were operated on *via* thoracoscopy, and the rest were operated on via open surgery. One neonate from the thoracoscopic group and seven from the open group were excluded due to protocol deviation. Thus, data of fifty-three babies were analyzed.

Amongst the fifty-three babies, twenty-eight were boys, and twenty-five were girls. All babies were operated on within the first seventy-two hours of life. Six babies were preterm, and all were operated upon *via* the open surgical approach. The comparative demographic profile is presented in Table 1.

Table 1: Demographic profile.

Characteristics	TR group (8)	OR group (45)	P-value
Gender (M/F)	6/2	22/23	0.173
Age (Day of life)	2.63 ± 2.066 (IQR 1-4.75)	3.16 ± 3.68 (IQR 1-3)	0.695
Weight (Kg)	2.32 ± 0.44 (1.6-2.9)	2.41 ± 0.46 (1-3.8)	0.618
Neonate at birth (Term/Preterm)	8/0	39/6	0.273
Mode of delivery (vaginal/LSCS)	5/3	31/14	0.721

On blood gas analysis, there was an increase in partial pressure of carbon dioxide, which stabilized after fistula ligation (Figure 2). The partial pressure of carbon dioxide in the thoracoscopic group was higher than that in the open group at all time points. This was, however, not reflected in the end-tidal capnography. In the immediate postoperative period, both groups of children had similar levels of partial pressures of carbon dioxide.

Respiratory acidosis improved throughout the surgery in the OR group, but in the TR group, the acidosis worsened at the time of positioning and ligating the fistula. By the end of the procedure, values returned to the baseline levels and improved during the immediate postoperative period (Table 2). The hemodynamic profile of the babies remained stable.

The period of intraoperative manual ventilation was higher in the thoracoscopic group than in the open repair group. The overall surgical and anesthesia duration was also longer for the thoracoscopic approach (Table 3).

Discussion

The use of minimally invasive surgical technique has been increasingly applied in neonates and children, leading to the use

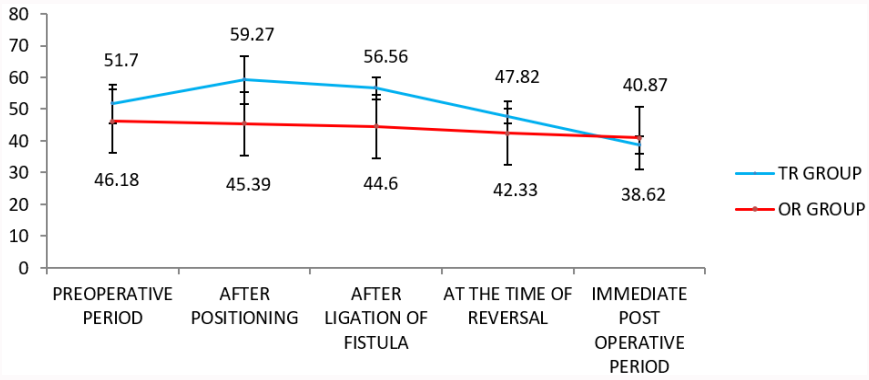

Figure 2: Trend of $PaCO_2$.

Table 2: Arterial blood gas values, $EtCO_2$, and vital signs at crucial time points.

Items	Preoperative		After positioning		After ligation of fistula		At the time of reversal		Immediate Postoperative	
	TR	OR	TR	OR	TR	OR	TR	OR	TR	OR
Ph	7.19 ± 0.1	7.13 ± 0.011	7.17 ± 0.12	7.17 ± 0.10	7.14 ± 0.08	7.21 ± 0.09	7.24 ± 0.08	7.24 ± 0.09	7.30 ± 0.1	7.27 ± 0.08
$PaCO_2$	51 ± 1	46 ± 13	59 ± 21	45 ± 15	56 ± 9	44 ± 11	47 ± 6	42 ± 9	38 ± 7	40 ± 8
$EtCO_2$	36 ± 3	40 ± 4	36 ± 3	40 ± 4	36 ± 4	36 ± 4	33 ± 3	35 ± 3	37 ± 5	36 ± 2
HR	142 ± 9	138 ± 13	144 ± 11	142 ± 8	144 ± 7	142 ± 9	143 ± 8	140 ± 8	145 ± 8	139 ± 8
SBP	82 ± 12	80 ± 12	81 ± 17	79 ± 12	80 ± 13	80 ± 10	80 ± 16	81 ± 11	80 ± 17	81 ± 11

Table 3: Overall surgical and anesthesia duration.

Characteristics	TR group Mean ± SD	OR group Mean ± SD	P-value
Manual Ventilation duration in minutes	100.50 ± 71.63	52.02 ± 17.44	0.001*
Surgery Duration in minutes	124.75 ± 46.42	94.91 ± 25.40	0.010
Anesthesia Duration in minutes	183.13 ± 44.95	140.84 ± 27.27	0.001

of thoracoscopy in neonates presenting with tracheoesophageal fistula [2-4]. The primary aim of our study was to see the trends and variations of hypercapnia and acidosis in the thoracoscopic and open repair of tracheoesophageal fistula. We found that most babies presented with baseline hypercarbia and acidosis. This was probably due to the primary pathology as most of the children presenting with tracheoesophageal fistula generally have lung contamination due to spillage from the pouch and aspiration of gastric contents through distal TEF that results in atelectasis and pneumonitis. After positioning and formation of capnothorax, there was an increase in partial pressure of CO_2 seen in the thoracoscopic group, which was not witnessed in the open repair group. This is probably because CO_2 insufflations compress both the lungs to achieve an adequate working space that causes an increase in the shunt fraction. Although the dependent lung is also compressed in open repair, adequate ventilation of the non-dependent lung achieves adequate CO_2 washout. The fact that despite an increase in CO_2 blood gas values, the end-tidal CO_2 values remained stable further supports that a capnothorax increases shunt fraction in the lungs. Bishay et al. conducted a randomized pilot trial in neonates to evaluate the effect of thoracoscopic surgery on neonatal arterial blood gases. They also noted increased and extreme values of $PaCO_2$ in the children undergoing thoracoscopic repair. Although they did not find a statistical difference regarding $PaCO_2$ and pH values, theirs was a feasibility study which compared five cases of each and was not powered for the same [5].

Our study did not note any change in hemodynamics with increased hypercarbia. In a case series of ten neonates undergoing thoracoscopic repair, the authors noted significant acidosis [6]. This fact, along with falsely low reading at times of hypercarbia as noted by our study, calls for increased vigilance and careful anesthetic management during thoracoscopic repair of TEF.

In our study, after the ligation of the fistula, there was a decrease in arterial $PaCO_2$ in both thoracoscopic and open repair groups, whereas the pH, $EtCO_2$ and hemodynamic parameters remained stable. By the end of surgery and in the immediate postoperative period, acidosis improved in both groups, followed by a decrease in $PaCO_2$ and $EtCO_2$ to baseline values. However, the changes were not statically significant. The manual ventilation duration, total duration of surgery, the entire time of anesthesia, and total mechanical ventilation duration were less in the open repair group. The CO_2 insufflation and lung compression caused neonates in thoracoscopic procedures to be vulnerable to sudden deoxygenation and hypercapnia, which needed more manual ventilation to check an acute rise in $EtCO_2$. Although the thoracoscopic approach in our institution appeared to take longer than the open approach, we believe this was a function of the learning curve inherent in the new technique.

Although randomized studies are limited to children, thoracoscopic surgery appears to offer outcomes at least equivalent to that of open operations with less postoperative pain, less scarring and a more rapid recovery. However, due to limited literature regarding the anesthetic management of tracheoesophageal fistula, complications of hypercapnia and acidosis and their management, it remains a challenge for anesthetists [7].

Our study has several limitations. First, the number of thoracoscopic cases done was considerably less than the open repair case. Second, since this was a non-randomized trial, there is selection bias in the selection of neonates for the thoracoscopic approach. Third, we did not do an extended follow-up to assess the impact of

the intraoperative metabolic changes.

In conclusion, thoracoscopic repair of TEF necessitates extra vigilance from the anesthesiologist to manage hypercarbia, especially post positioning before fistula ligation. Open repair of the tracheoesophageal fistula is associated with lesser manual ventilation duration, surgery duration, and anesthesia duration. However, in future, further studies with larger sample sizes and longer follow-ups will be required to validate the results.

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