Reports of Investigation

D.E. Soliman MD,
A.D. Maslow MD,
P.M. Bokesch MD,
M. Strafford MD,
L. Karlin MD,
J. Rhodes MD,
G.R. Marx MD

Transoesophageal echocardiography during scoliosis repair: comparison with CVP monitoring

Purpose: Accurate haemodynamic assessment during surgical repair of scoliosis is crucial to the care of the patient. The purpose of this study was to compare transoesophageal echocardiography (TEE) with central venous pressure monitoring in patients with spinal deformities requiring surgery in the prone position.

Methods: Twelve paediatric patients undergoing corrective spinal surgery for scoliosis/kyphosis in the prone position were studied. Monitoring included TEE, intra-arterial and central venous pressure monitoring (CVP). Haemodynamic assessment was performed prior to and immediately after positioning the patient prone on the Relton-Hall table. Data consisted of mean arterial blood pressure (mBP), heart rate (HR), CVP, left ventricular end-systolic and end-diastolic diameters (LVESD and LVEDD respectively) and fractional shortening (FS). Right ventricular (RV) function and tricuspid regurgitation (TR) were assessed qualitatively. Analysis was performed using descriptive statistics, Student's t test, sign rank , and correlation analysis.

Results: There was an increase in CVP (8.7 mmHg to 17.7 mmHg; $P < .01$), and decreases in LVEDD (37.1 mm to 33.2 mm; $P < .05$), and mean blood pressure (75.0 mmHg to 65.7 mmHg; $P < .05$) when patients were placed in the prone position. Fractional shortening, LVESD, and HR did not change from the supine to the prone position. Right ventricular systolic function and tricuspid regurgitation were unchanged.

Conclusion: These data indicate that the CVP is a misleading monitor of cardiac volume in patients with kyphosis/scoliosis in the prone position. This is consistent with previous studies. In this clinical situation, TEE may be a more useful monitoring tool to assess on-line ventricular size and function.

Objectif : L'évaluation hémodynamique précise pendant la correction chirurgicale d'une scoliose est déterminante pour les soins donnés au patient. Le but de l'étude actuelle était de comparer l'échographie transœsophagienne (ETO) au monitorage de la pression veineuse centrale chez les patients souffrant de déformations rachidiennes nécessitant une chirurgie en décubitus ventral.

Méthodes : Douze patients pédiatriques devant subir, en décubitus ventral, une chirurgie de correction pour une scoliose ou une cyphose ont été étudiés. Le monitorage comprenait l'ETO, la mesure de la pression intra-artérielle et de la pression veineuse centrale (PVC). L'évaluation hémodynamique a été faite avant et immédiatement après l'installation du patient en décubitus ventral sur la table Relton-Hall. Les données comportaient la tension artérielle moyenne (TAm), la fréquence cardiaque (FC), la PVC, les diamètres ventriculaires gauches télosystolique et télodiastolique (DVGTS et DVGTD respectivement) et le raccourcissement fractionnaire (RF). La fonction du ventricule droit (VD) et la régurgitation tricuspidienne (RT) ont été évaluées qualitativement. L'analyse a été réalisée à partir de statistiques descriptives, du test t de Student, du test de rang et de l'analyse de corrélation.

Résultats : Il y a eu un accroissement de la PVC (de 8,7 mmHg à 17,7 mmHg ; $P <,01$), et une diminution du DVGTD (de 37,1 mm à 33,2 mm ; $P < 0,05$) et de la tension artérielle moyenne (de 75,0 mmHg à 65,7 mmHg ; $P < 0,05$) quand les patients ont été placés en décubitus ventral. Le raccourcissement fractionnaire, le DVGTS et la FC n'ont pas été modifiés lors du changement de position, de la position couchée au décubitus ventral. La fonction systolique du ventricule droit et la régurgitation tricuspidienne n'ont pas changé.

Conclusion : Ces résultats indiquent que la PVC n'est pas un moniteur fiable du volume cardiaque chez les patient souffrant de cyphose ou de scoliose, placés en décubitus ventral. Cela correspond aux études antérieures. Dans cette situation clinique, l'ETO peut être un outil de surveillance plus utile pour une évaluation en ligne de la taille et de la fonction ventriculaires.

From the Departments of Anaesthesia, New England Medical Center and Beth Israel-Deaconess Medical Center, Boston MA, and Departments of Orthopaedic Surgery and Cardiology, New England Medical Center, Boston MA.

Address correspondence to: Andrew Maslow MD, Department of Anesthesia and Critical Care, Beth Israel Deaconess Medical Center, 330 Brookline Ave, Stoneman 308, Boston Ma, 02215. Phone: 617-667-3112; Fax: 617-667-7849.

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SURGICAL correction of scoliosis/kyphosis may involve extensive fusion of the spine, sometimes including the entire length of the thoracic and lumbar regions. Typically a posterior approach is used, with the patient placed in the prone position.[1]

Causes of cardiovascular instability may be multifactorial including blood loss, fluid shifts, co-existing cardiac pathology, and the haemodynamic effects of the prone position.[1-3] Therefore, assessment of the patients intravascular volume and cardiac function is crucial to the haemodynamic management of the patient.

Haemodynamic monitoring may include standard noninvasive monitoring, invasive blood pressure monitoring (A-line), and, in some cases, central pressure monitoring (central venous pressure, or pulmonary artery pressure).[4] Studies, involving other surgical procedures, have suggested that transoesophageal echocardiography (TEE) may provide superior information regarding cardiac function during surgery.[5-10]

The purpose of this study was to examine the use of TEE monitoring, compared with monitoring central venous pressure in paediatric patients undergoing surgical repair of kyphosis/scoliosis.

We hypothesized that central venous pressure (CVP) may be misleading in the assessment of cardiac volume. We also hypothesized that TEE may be a more accurate monitor during surgical repair of scoliosis in the paediatric patient while in the prone position.

Methods and materials

Patient population

After institutional review board approval and parental consent, 12 patients with kyphoscoliosis undergoing surgical repair in the prone position were studied. Demographic data (Table I) included age, weight, aetiology of spinal deformity, surgical procedure, cardiac, and pulmonary evaluation. The degree of skeletal curvature was assessed preoperatively by the orthopaedic surgeon (LK). Severity of spine disease was based on the degree of curvature of the thoracic spine.

Study protocol

Anaesthetic induction and maintenance was at the discretion of the attending anesthesiologist. In most cases a balanced technique (fentanyl, nitrous oxide, isoflurane) was used except where malignant hyperthermia precautions prevented the use of isoflurane. Monitoring included ECG, end tidal carbon dioxide, pulse oximetry, tidal volume and rate, airway pressures, and bladder catheter. Invasive monitors, placed after induction of general anaesthesia, included intra-arterial and central venous catheters in all patients. At the discretion of the attending anesthesiologist, three patients had a pulmonary artery catheter (PAC) placed based on suspected and/or known cardiopulmonary disease. Pressure transducers were placed at the level of the right atrium at the midaxillary line. A biplane TEE probe (Hewlett Packard, Andover Ma.) was placed after induction of general anaesthesia and intubation. The TEE studies and haemo-

TABLE I Demographic data of study patients. Etiology of spine deformity is listed as idiopathic, neuromuscular, or other. Recorded cardiac history includes evidence of or presence of congenital heart disease (CHD).

Pt	*Age yr*	*Wt kg*	*Etiology of Spine deformity*	*Scol/Kyph*	*Angle and direction (degrees; direction (R,L); site (thor/lumb); type (Scol/Kyph))*	*Surgery*	*ECG/Echo*	*PFTs*
1	9	20	neuromuscular	kyphscol	56;L;Thor Scol	Post/Kyph	NA	RLD
2	14	35	neuromuscular	scoliosis	58;L;Thor Scol//54;R;Thor Scol// 32;L;Thorlumb Scol	AntPost	RVE/PHTN	RLD
3	17	33	neuromuscular	scoliosis	57;R;Thorlumb Scol//100;L;Lumb Scol	Post	normal	RLD
4	5.5	15	neuromuscular	scoliosis	160; Lumb Scol	Post	NA	RLD
5	18	77	idiopathic	kyphosis	49;Thor Kyph//64;Lumb;Lordosis	AntPost	normal	normal
6	14	45	congenital	scoliosis	69;L;Thor Scol//55;L;Lumb Scol	AntPost	NA	NA
7	13	23	congenital, neuromuscular	kyphoscol	123;L;Thor Scol//89;Thorlumb Lord. 92;Lumb Kyph	Post	RVH	RLD
8	15	36	idiopathic	scoliosis	82;R;Thorlumb Scol//42;L;Lumb Scol	Post	normal	RLD
9	14	45	neuromuscular	kyphosis	133;Thor Kyph	AntPost	NA	NA
10	12	25	neuromuscular	scoliosis	61;L;Thor Scol//47;R;Lumb Scol	Post	NA	NA
11	10	27	neuromuscular	scoliosis	38;R;Thor Scol//58;L;Lumb Scol	Post	NA	NA
12	14	32	Marfan's	scoliosis	52;R;Thor Scol//55;L;Lumb Scol	Post	LVH	NA

L=Left; R=Right: Thor=Thoracic; Lumb=Lumbar; ThorLumb=ThoracicLumbar: Scol=Scoliosis; Kyph=Kyphosis; Lord=Lordosis: Post=Posterior Spinal Fusion; AntPost=Anterior release and Posterior approach to spine fusion; Kyph=kyphectomy: ECG/Echo= electrocardiogram/echocardiogram; NA=not done; normal=either read as normal or no abnormalities listed; RVE=right ventricular enlargement; PHTN=pulmonary artery hypertension; RVH=right ventricular hypertrophy; LVH=left ventricular hypertrophy: PFTs=pulmonary function tests; RLD restrictive lung disease dynamic variables were simultaneously recorded at end expiration. Echocardiographers were blinded to haemodynamic data. Recorded haemodynamic data consisted of mean arterial blood pressure (mBP), heart rate (HR), and mean central venous pressure (CVP). In three patients, mean pulmonary artery pressures (mPAP) were measured. After haemodynamic stability was established (± 20% of pre-induction HR and mBP), all baseline measurements were recorded in the supine position. Patients were then placed on four individual adjustable supports on a rail system (Relton-Hall table) allowing accurate positioning irrespective of the skeletal deformity.[11] The surgeon and anesthesiologist confirmed that the chest wall and abdomen were free of external compression. Decreases in blood pressure were treated with intravenous fluid while increases in blood pressure were treated with fentanyl and isoflurane. Attempts were made to maintain mBP and HR, after placement in the prone position, within 20% of the supine measurements.

Qualitative TEE assessment of ventricular systolic function and volume was performed on-line while quantitative measurements of ventricular function were performed off-line. Measurement of the fractional shortening (FS) was used to assess systolic function.[12] Echocardiographic images of the left ventricle were obtained at the gastric mid-papillary muscle level using a short axis view. Left ventricular end-systolic and end diastolic diameters were measured using leading edge to leading edge of the endocardial borders (LVESD and LVEDD respectively).[12] Fractional shortening (FS) was calculated as shown below:

$$FS = (LVEDD-LVESD)/LVEDD$$

Echocardiographic measurements were the mean of three consecutive cardiac cycles.

Right ventricular (RV) function and tricuspid regurgitation (TR) were assessed qualitatively. Images of the right heart structures were obtained from a variety of angles and locations. All echocardiographic measurements and evaluations were performed by experienced echocardiographers (ADM, GM, JR), all of which were blinded to the haemodynamics and the degree and location of spinal curvature.

TABLE II Haemodynamic data.

Pt	*supine*							*prone*						
	HR	*mBP*	*CVP*	*PAP*	*LVEDD*	*LVESD*	*FAS*	*HR*	*mBP*	*CVP*	*PAP*	*LVEDD*	*LVESD*	*FAS*
1	149	55	5		27	13.5	.5	176	50	9		25	11	.6
2	85	73	13		39.3	23	.4	85	63	14		43.3	26	.4
3	85	63	9		39.3	17.5	.6	100	50	23		39.3	20.6	.5
4	115	60	5		29.3	18.7	.4	117	60	6		30.6	15.6	.5
5	85	95	7		64	26	.6	90	53	12		54	38	.3
6	92	65	17	21/11	39	20.4	.5	83	73	29	44/28	31.9	19.5	.4
7	110	110	6		25	15	.4	140	92	31		17.6	9.7	.4
8	80	93	6		34.6	19	.5	80	77	17		28.5	15.6	.5
9	105	70	6		37.2	22.1	.4	90	55	10		32.3	17.8	.4
10	77	85	4	29/9	42	25	.4	75	78	9	37/23	45	29	.4
11	100	70	17		33.7	18.2	.5	100	87	21		26.4	15.8	.4
12	60	57	10	13/3	34.5	21	.4	95	50	31	32/18	24	13	.3

HR=heart rate (bpm); mBP=mean blood pressure (mmHg); CVP=central venous pressure (mmHg); LVEDD=left ventricular end diastolic diameter (mm); LVESD=left ventricular end systolic diameter; FAS=Fractional area shortening.

TABLE III Changes when patients are placed in the prone position on the

Heart Rate (bpm)		mean Blood Pressure (mmHg)		Central Venous Pressure (mmHg)	
supine	prone	supine	prone	supine	prone
94.9 ± 6.4	102.6 ± 8.4	75.0 ± 4.9	65.7 ± 4.4*	8.7 ± 1.3	17.7 ± 2.5†
LVEDD (mm)		**LVESD (mm)**		**FAS**	
supine	prone	supine	prone	supine	prone
37.1 ± 2.9	33.2 ± 3.0*	20.0 ± 1.1	19.3 ± 2.4	45.0 ± 2.0	43.0 ± 2.0

Mean ± standard error (SE).

LVEDD=Left Ventricular End Diastolic Diameter; LVESD=Left Ventricular End Systolic Diameter; FAS=Fractional area shortening

P values when compared to supine position: * = <.05; † = <.01

Data analysis

Data were analysed using Student's paired t test and sign rank test (CVP) where applicable. $P < .05$ was considered significant. Data are presented as mean ± standard error. Correlation coefficient was used to assess the relationship between changes in haemodynamics, and severity of spinal disease. Data analysis was performed using SAS Stat software.

Results

Twelve patients were studied. Demographic and procedure data are presented in Table I. Haemodynamic data is presented in Table II. Causes of spinal diseases included neuromuscular (7) idiopathic (2), congenital (1), combined congenital and neuromuscular (1), and Marfan's disease (1).

In all patients, the short axis view of the left ventricle at the level of the gastric mid-papillary muscle was obtained. In all patients, RV function and TR was able to be assessed from either esophageal or gastric views but not both.

All patients were in sinus rhythm throughout the study. Central venous pressure increased (8.7 to 17.7 mmHg; $P < .01$) when the patient was placed in the prone position while LVEDD (37.1 to 33.2mm; $P = .02$) and mBP (75.0 to 65.7 mmHg; $P = .048$) decreased (Table III; Figures 1, 2). Changes in fractional area of shortening (FS) (.45 to .43), LVESD (20.0 mm to 19.3 mm), and HR (94.9 bpm to 102.6 bpm) were not statistically significant (Table III; Figures 1, 2). Qualitative assessment of the right heart showed no change in RV function or amount of TR. Quantitative analysis of the right heart structures were difficult since we were unable to uniformly obtain a standard image in all patients in the prone position. Views obtained were from both oesophaphageal and gastric images. All central catheters were reported to be at the junction of the superior vena cava and right atrium or in the SVC on post operative chest x-ray.

All patients had thoracic spine disease except patient # 4, who had lumbar scoliosis. In this patient, there was no haemodynamic change when placed in the prone position. Patients # 1, 5, 6, 7, 8, 9, 11, and 12 had, both, increases in CVP and decreases in LVEDD. In patient # 3, the CVP increased while LVEDD did not change. Of these, patients #6 and #11 had increases in mBP while the remainder had reductions in mBP.

Preoperative data are presented in Table I. Evaluations were not done uniformly. There was no ECG nor Echo in five patients, while PFTs were not performed in five patients. In four patients, neither cardiac nor pulmonary tests were done. Four of six patients with cardiac evaluation had some abnormality while six of seven patients with PFTs had evidence of restrictive lung disease.

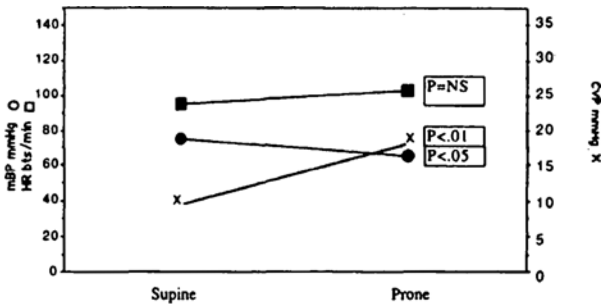

FIGURE 1 Line chart showing the change in haemodynamic measurements when placed in the prone position. The left abscissa shows the scale for heart rate (HR) and mean blood pressure (mBP). The abscissa on the right shows the scale for central venous pressure (CVP). Mean data for 12 patients.

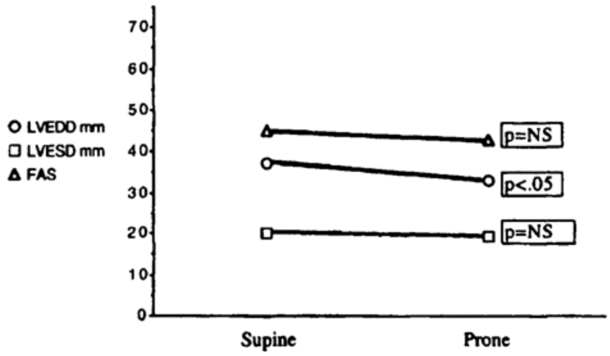

FIGURE 2 Mean changes in echocardiographic measurements when placed in the prone position. Data includes left ventricular end diastolic (LVEDD) and systolic (LVESD) and fractional shortening (FS; LVEDD-LVESD/LVEDD).

Correlation analysis between changes in CVP and severity of spine disease revealed r values of .54 ($P = .07$). There were no correlations between the changes in haemodynamic measurements in the group as a whole.

In three patients pulmonary artery pressures (PAP) were measured. When these patients were placed in the prone position, pulmonary artery pressures increased. In the supine position the mean PAP was 12.7 and in the prone position it increased to 28.0 mmHg. The LVEDD remained the same or decreased in all three cases. Given that only three patients had pulmonary artery catheters, no statistical analysis was performed.

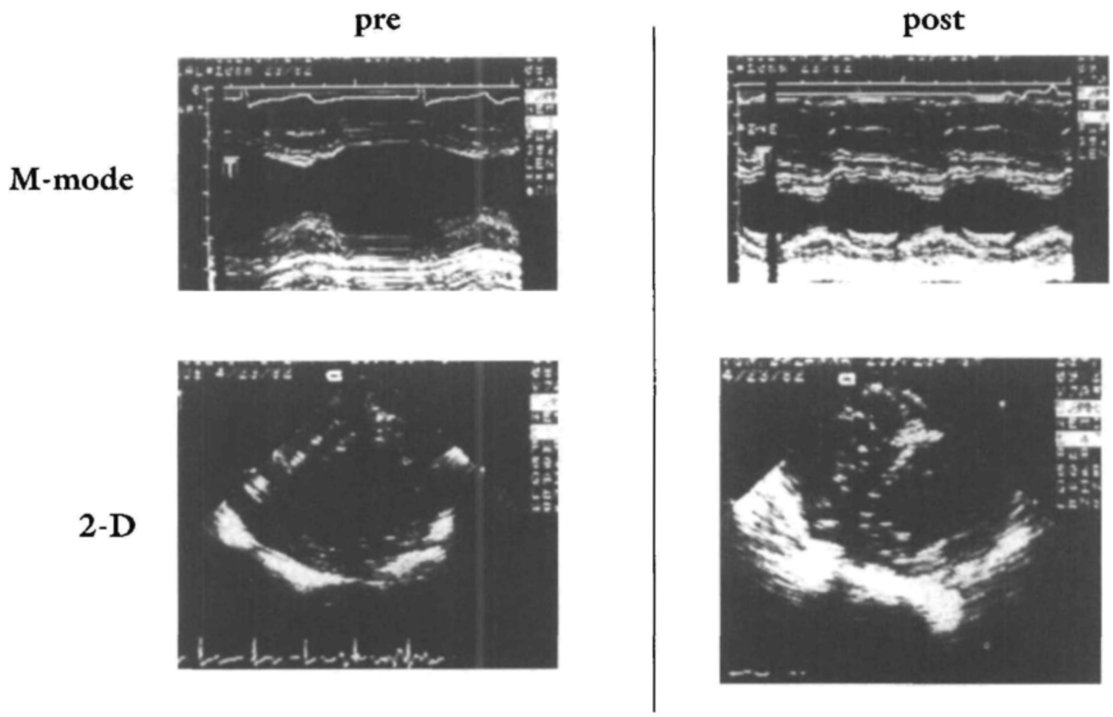

FIGURE 3 Echocardiographic images of patient #12. The images to the left (on top) represent the supine and the images to the right (on bottom) are those obtained when the patient was placed prone. The images show the reduction in cavity size when placed in the prone position. Associated haemodynamic changes (Table II) showed increased CVP, mPAP, HR, and decrease in BP.

Patients #7 and #12 had been previously cancelled because of severe haemodynamic instability after being positioned prone on the Relton Hall frame. Both patients were rescheduled and underwent surgery during this study.

Figure 3 shows the echocardiographic images from patient #12 during the second surgery. This patient had Marfan's disease. The first operation was complicated by hypotension and subsequent ventricular tachycardia after being placed in the prone position. The patient was resuscitated, the case was cancelled, and subsequently underwent a cardiac and pulmonary work-up, which showed left ventricular hypertrophy. The patient was brought back to the operating room for a second attempt, which was done during this study. Echocardiographic analysis showed a decrease in LVEDD and LVESD when placed in the prone position (Figure 3). Haemodynamic measurements showed a reduction in mBP and increases in both CVP and mPAP. This case and case #7 were successfully completed using TEE as a guide to fluid management. The CVP remained > 25 mmHg in both cases while in the prone position. At no time during either case, was there evidence of ventricular systolic dysfunction according to on-line qualitative analysis. After reviewing the initial attempts at surgical correction, when the CVP was > 20 mmHg, vasopressors and inotropes were administered with the assumption of ventricular failure.

Discussion

Surgery for scoliosis/kyphosis repair may be associated with massive blood loss, fluid shifts, and haemodynamic lability.[1,13] Much of the bleeding is from vertebral venous plexuses. Several methods have been employed to reduce bleeding, including the use of the Relton-Hall frame,[11] and hypotensive anaesthesia technique.[1,13] Assessment of the patient's intravascular volume and cardiac function is crucial to safe and effective management.

Our results demonstrated that, when placed prone, there was an increase in central venous pressure, a decrease in LVEDD, and no overall change in systolic function, as measured by FS. Systolic function seemed to be preserved in all patients except patient #5, who demonstrated a reduction in FS from 0.6 to 0.3. In reviewing two cases (#7 and #12) done during this study, that had previously been cancelled due to severe hypotension and elevated CVP, it was apparent during the second operation, using TEE, that the elevated CVP did not accurately reflect preload, and its high value was misinterpreted as ventricular failure. Using TEE to monitor cardiac function, both cases were completed without complication. Similar changes were seen in those patients monitored with a pulmonary artery catheter. Central pressure monitors did not reflect changes in the TEE and mBP from the supine to the prone position.

We did not find any correlation between the degree of thoracic spine disease and changes in CVP. This may be explained by the variety of spine disease and sample size. Similarly, correlation of haemodynamic changes were not found, in part due to attempts keep prone mBP and HR within 20% of supine values using intravenous fluid. This would minimize changes in ventricular cavity dimensions. Despite this, there were, overall, decreases in mBP and LVEDD while CVP increased. The LVESD and FS decreased, but these changes were not statistically significant, with the exception of one patient (#5).

The structural changes of the kyphoscoliotic or scoliotic patient result in decreases in total pulmonary compliance, leading to a progressive restrictive respiratory pattern, alveolar hypoventilation, and increased pulmonary vascular resistance and may progress to Cor pulmonale.[1,13-15] An echocardiographic study demonstrated early increases in pulmonary vascular resistance and right ventricular size, and a decrease in left ventricular size in the absence of other clinical or laboratory evidence of abnormal pulmonary function.[16] Our results may have been related to changes in baseline cardiac and pulmonary function in these patients. Since there was no uniformity in preoperative testing it is difficult to perform a statistical analysis.

Prone positioning is thought to affect cardiovascular function due to changes in intra abdominal and thoracic pressures resulting in decreases in preload to the heart. Relton and Conn, using angiography, demonstrated compression of the inferior vena cava in scoliotic patients.[17] Wadsmorth *et al.*,[18] using transthoracic bioimpedence to measure cardiac output, showed reduction in cardiac output when healthy volunteers were placed in the prone position. Using thermodilution cardiac output measurement, inferior vena caval pressure monitors, Yokoyamo *et al.*[19] showed reductions in cardiac output, in normal patients, without changes in both central and inferior caval pressures. Changes in autonomic balance may explain the lack of changes in pressures. Finally Lange *et al.*,[20] using thermodilution cardiac output and ventriculography, showed that changes in position resulted in increases in both left and right ventricular diastolic pressures without changes in ventricular volumes. They suggested that there was a decrease in ventricular distensibility. All these studies were performed in patients with relatively normal thoracic dimensions. Hypothetically, these changes may be greater with thoracic spine pathology. The Relton-Hall table is designed to reduce these changes.[11] Improper positioning could cause excessive intrathoracic and intrabdominal pressures, reduced venous return, increased extradural veins volume from venous congestion, and subsequent increases in venous bleeding in the surgical field.

Changes in the position of mediastinal structures with assumption of the prone position may have caused impedance to ventricular inflow. Patients with kyphoscoliosis may demonstrate a decrease in the anterior-posterior diameter of the thoracic cavity. It is possible that the prone position may further reduce the space in the mediastinum and/or alter thoracic pressures. Mechanical compression of the mediastinal structures may result in impaired ventricular filling and elevation in central pressures. This was suggested as a cause in sudden cardiac collapse in previous case reports.[2,3] Elevation of the thoracic spine relieved the hypotensive episodes in one report, which were thought to be due to antero-posterior compression of the mediastinum during decortication.[2] Impaired venous return due to caval compression would result in a decrease in LVEDD as well as a decrease in CVP. Haemodynamic and TEE changes seen in our study seem to be more consistent with compression of the mediastinal structures and impaired ventricular filling as opposed to caval compression.

Studies demonstrating poor relationship between central pressures and ventricular pre-load have been seen elsewhere in cases of major vascular and cardiac surgery.[5-10] However, other studies have shown that the CVP may reflect changes in blood volume.[21,22] A study in adult cardiac surgical patients showed that the CVP adequately reflected graded hypovolaemia compared with other haemodynamic indices in patients with both normal and abnormal ventricular function.[22] Studies in which changes in pressures poorly reflected changes in volumes may simply be describing the effects of altered ventricular compliance.[5-10] These studies did not incorporate a graded volume change to assess whether pressures can be used to follow trends. In a more recent study, TEE was compared with pulmonary capillary wedge pressure (PCWP) during increasing volume administration in dogs.[23] Both measurements were compared with cardiac output (CO) and left ventricular stroke work (LVSW). Changes in end diastolic area (EDA) were related to changes in CO and LVSW, while changes in PCWP were not. The PCWP reflected early changes in cardiac indices, but failed to demonstrate the similar "ceiling effect" seen in the other measurements. This shows the limitations in assessing ventricular function with pressure monitoring when the compliance of the ventricle is either changed or there is movement to the steep portion of the compliance curve.[24]

If filling of the cardiac chambers is impaired in the prone position then this may create caval congestion resulting in congestion of the head and neck veins as well as the extradural veins. The latter may cause increases in blood loss from vertebral venous plexuses. If this were the case, then a technique should be sought to relieve any impedance in cardiac filling (e.g. positioning of components of the Relton-Hall frame). This may result in improve haemodynamics and reduction in blood loss.

There are several limitations to the study. A larger sample size and uniformity in preoperative cardiopulmonary testing may have allowed correlation analysis between severity of spinal curvature, cardiopulmonary function, and intraoperative haemodynamic changes.

Quantitatively analysis of right ventricular function, pulmonary artery catheters in all patients, and recorded data during periods of controlled volume changes would have allowed more complete pressure-volume assessment of the ventricles.[17] While visual estimation of ventricular function has been shown to be accurate in general assessment,[25] it is difficult to perform statistical analysis. We did not attempt to perform quantitative analysis of the right ventricle since we were not able to obtain the same image uniformly in all patients i.e. in some patients right heart function and size were assessed from esophageal views (from a variety of angles), while in others it was assessed using gastric views. Quantitative assessment would have been useful to further assess ventricular pre-load especially when comparisons are made to the CVP, which may more accurately reflect right heart pressures and preload as opposed to left heart data.

Transducer position may contribute to changes in pressures with changes in patient position. All CVP transducers were placed at the level of the mid-axillary line, assuming this to be the level of the right atrium. This was repeated upon turning the patient prone. However, in the absence of radiologic evaluation of the position of heart in the thorax it is difficult to know where the transducer should be positioned. We did not perform intraoperative radiological examinations to evaluate this nor were the CVP catheters seen in the cardiac chambers with the TEE. Rajacich *et al.*[26] showed that changes in position resulted in decreased correlation between the pulmonary capillary wedge pressure and the left atrial pressure. This may be due to changes in West's lung zones. Assuming the tip of the pulmonary artery catheter was initially placed in zone III, placement in the prone position may cause changes in the ventilation and perfusion distribution such that the tip of the catheter may now lie in zone I or II. In these latter zones there is greater resistance to blood flow.[27] The correlation between the central venous pressure and the left atrial pressure, however, remained constant.

Other TEE measurements that may have shed light on the causes of the observed haemodynamic changes would have included trans-mitral and/or tricuspid flows and pulmonary and/or hepatic or caval flows. The measurements used, however, were simple and quick, and should be easily acquired by an examiner with basic echocardiographic knowledge.

We did not standardize the anaesthetic regimen, nor did we employ any advanced technology to monitor anaesthetic depth. These variables certainly effect autonomic responses. While it may be argued that this may have altered our results, we feel that since each patient acts as his/her own control that these variables are less important.

Conclusion

This study suggests that the CVP does not accurately reflect changes in ventricular preload in paediatric patients undergoing corrective surgery for scoliosis when placed in the prone position. Changes in CVP seem to be unreliable in some patients, but further evaluation of the response of CVP to fluid challenges are needed to assess whether CVP monitoring would be useful. Transoesophageal echocardiographic evaluation is able to provide on-line evaluation of ventricular cavity size and function, and therefore, may more accurately reflect the patient's haemodynamic state in this patient population.

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