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Hemodynamic and ventilatory changes in thoracolumbar surgery. Comparative analysis of two types of intraoperative positioning

Cambios hemodinámicos y ventilatorios en cirugía toracolumbar. Análisis comparativo de dos tipos de posicionamiento intraoperatorio

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Keywords: lumbar positioner, oxygen pressure, bleeding, hemodynamic response, tranexamic acid, spine.

Palabras clave: *posicionador lumbar, presión de oxígeno, sangrado, respuesta hemodinámica, ácido tranexámico, columna vertebral.*

ABSTRACT

Introduction: during spinal surgical procedures, proper prone positioning is essential to reduce intra-abdominal pressure and prevent hemodynamic and ventilatory physiological alterations. **Material and methods:** a randomized observational comparative case-control study was conducted at a national tertiary referral center for spine surgery. Forty-three patients who underwent posterior thoracic and lumbosacral spine surgery over a one-year period were evaluated. Patients were classified according to the spinal segment involved, type of instrumentation, and intraoperative positioning using surgical bolsters. Statistical validity and correlations were assessed using Spearman's Rho. **Results:** the study population consisted of 36 male and seven female patients, with a mean age of 39.1 ± 21.1 years. The sensitivity phase was based on the evaluation performed by five fellowship-trained spine orthopedic surgeons at this institution. Hemodynamic and ventilatory changes were assessed in the preoperative, intraoperative, and postoperative periods in patients undergoing posterior thoracolumbar instrumentation, using bolster configuration (longitudinal vs transverse) as the primary variable. 18 patients were positioned using longitudinal bolsters and 25 using transverse bolsters. Significant hemodynamic differences were identified between bolster configurations, with greater intraoperative blood loss observed in patients positioned with transverse bolsters compared with longitudinal bolsters (Spearman's Rho, $p = 0.025$). Additionally, a strong positive correlation was observed between tranexamic acid administration and reduced intraoperative blood loss, with a 99% confidence level (Spearman's Rho, $p < 0.01$). Ventilatory changes were also identified, with higher intraoperative FiO_2 requirements in patients positioned with transverse bolsters compared with longitudinal bolsters ($p = 0.030$). **Discussion:** based on the available literature, there are no comparable studies directly evaluating these variables, limiting positive or negative comparisons. Therefore, this study establishes a clinically relevant precedent for future research. **Conclusion:** longitudinal bolster positioning is associated with reduced intraoperative blood loss and lower oxygen requirements. Tranexamic acid administration decreases intraoperative bleeding in both groups, with a greater hemodynamic benefit observed when combined with longitudinal bolster positioning.

Grade of recommendation: B
Level of evidence: II-3

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RESUMEN

Introducción: *durante los procedimientos quirúrgicos de columna, el correcto posicionamiento prono del paciente es fundamental para disminuir la presión intraabdominal y evitar cambios fisiológicos hemodinámicos y ventilatorios.* ***Material y métodos:*** *se realizó un estudio de casos y controles aleatorizado observacional comparativo en un centro de concentración nacional para cirugía de columna vertebral de tercer nivel. Se evaluaron 43 pacientes intervenidos mediante abordaje posterior de segmento torácico y lumbosacro durante un año en el servicio de cirugía de columna. Los pacientes se clasifican según el segmento de columna afectado, la instrumentación a realizar y durante cirugía la colocación de rodillos como posicionadores, con una validez evaluada mediante Rho de Spearman.* ***Resultados:*** *36 masculinos, siete femeninas, 39.1 ± 21.1 edad promedio. La fase de sensibilidad fue basada en cinco ortopedistas con alta especialidad en cirugía de columna adscritos a esta unidad médica. Evaluando los cambios hemodinámicos y ventilatorios en pacientes pre, trans y postquirúrgico en instrumentaciones posteriores de segmento toracolumbar, tomando como punto de partida el acomodo de rodillos entre la mesa quirúrgica y el paciente (longitudinal-transverso). Se analizaron 18 pacientes con una configuración longitudinal y 25 pacientes con colocación transversa. Se encontró la existencia de cambios hemodinámicos entre la colocación de rodillos longitudinales vs transversos, presentando mayor sangrado la colocación transversa versus longitudinal con una validez evaluada mediante Rho de Spearman (0.025 < 0.05). Agregado se correlacionó la variable positiva alta entre el uso de ácido tranexámico y disminución del sangrado transquirúrgico con un nivel de confianza del 99% validado mediante Rho de Spearman (0.00 < 0.01). Se demuestran los cambios ventilatorios, presentando mayor requerimiento de volumen de oxígeno* FiO_2 *en pacientes con colocación de rodillos transversos versus longitudinales con un p-valor (0.030 < 0.05) según Rho de Spearman.* ***Discusión:*** *basado en revisiones de literatura, no se cuenta con estudios similares con los cuales se puedan comparar nuestros resultados de manera positiva o negativa, por tal motivo, se establece un precedente de alto impacto para futuros estudios.* ***Conclusión:*** *la colocación de rodillos longitudinales, presenta menor sangrado transquirúrgico, así como, menor requerimiento de volumen de oxígeno. El uso de ácido tranexámico disminuye la cantidad de sangrado en ambos grupos de pacientes, teniendo una asociación positiva de mayor impacto en la reducción de cambios hemodinámicos por sangrado si se asocia acido tranexámico con colocación de rodillos longitudinales.*

Grado de recomendación: *B*
Nivel de evidencia: *II-3*

INTRODUCTION

Prone positioning is commonly used to access the thoracic, lumbar, and sacral segments of the spine. Therefore, appropriate setup of the operating table and the positioning accessories employed are essential not only to ensure patient comfort but also to prevent hemodynamic and ventilatory physiological alterations.

The prone position induces a physiological adaptation in response to sustained pressure exerted on the anterior thoracic and abdominal walls. This continuous, moderate-intensity pressure is transmitted to the inferior vena cava, resulting in significant redistribution of venous blood toward the vertebral venous system. In clinical practice, surgeons frequently prioritize optimal exposure of the anatomical area to be addressed, potentially overlooking the associated hemodynamic and ventilatory consequences of patient positioning.

The most commonly used bolster configurations during prone positioning are longitudinal and transverse; however, current literature lacks sufficient evidence to establish which configuration is physiologically superior.

As it is a common practice in our national surgical and economic environment, the aim is to document the existence of hemodynamic and ventilatory changes related to the placement of soft positioners based on 15 cm high rolls of fabric and thereby set a precedent for future research of greater scope.

The vertebral venous system is anatomically connected to the thoracic region through the spinal canal and to the abdominal and pelvic regions via intercostal, lumbar, and other venous pathways. Oscar Batson was a pioneer in experimental studies involving non-human primates, demonstrating that in the presence of inferior vena cava occlusion, non-arterial venous return from the lower extremities tends to be redirected toward the vertebral venous system.

This system thereby functions as an auxiliary venous drainage pathway, known as the Batson vertebral venous plexus *(Figure 1)*.[1]

In patients with an elevated body mass index, adoption of the prone surgical position alters respiratory mechanics due to reduced thoracic expansion, thereby requiring higher tidal volumes and increased oxygen concentrations. It has been documented that elevated vertebral venous pressure may result in decreased spinal cord arterial pressure, consequently exposing the patient to a higher risk of neurological injury.[2,3]

Several strategies for operating table positioning have been proposed, including the so-called *Muslim prayer position*, kneeling position, and flexed positioning. These configurations result in marked flexion of the spine, hips, and knees, potentially leading to vascular and neural compromise at these levels. Consequently, multiple positioning devices have been developed to facilitate safe prone positioning during spine surgery, such as the Canadian frame, Relton-Hall frame, Andrews table, and Wilson frame *(Figure 2)*. In resource-limited settings where such devices are unavailable, alternative positioning adaptations are commonly employed, including the use of two longitudinal or two transverse bolsters, depending on the surgical modality and the surgeon's experience *(Figure 3)*.[1]

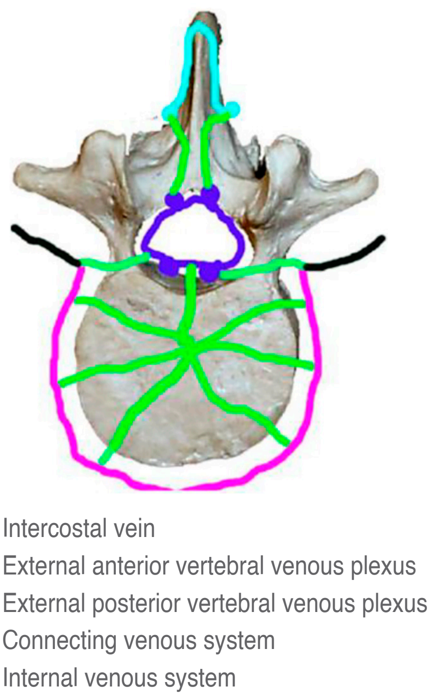

Figure 1: Batson's vertebral venous plexus.
Image reproduced from: Schonauer C et al.[1]

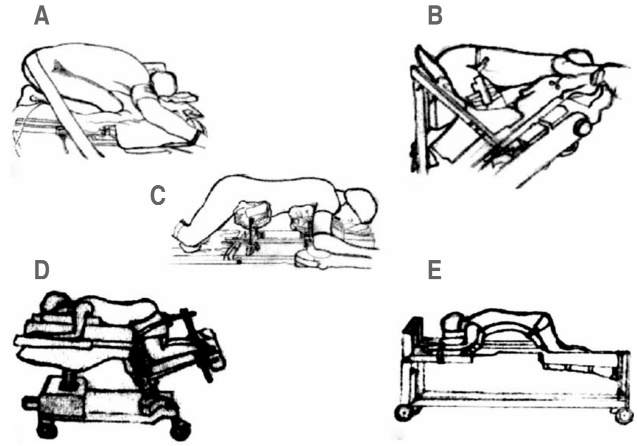

Figure 2: Patient positioning for spine surgery. **A)** Flexed position. **B)** Canadian frame. **C)** Relton-Hall frame. **D)** Andrews table. **E)** Wilson frame.

Several studies have demonstrated aortic mobilization and displacement associated with patient repositioning from the supine to the prone position, further influenced by the placement of anterior thoracic and abdominal supports. A thorough understanding of the physiological dynamics experienced by the patient during repositioning and padding is therefore essential for adequate surgical preparation and operative planning, as it allows identification of the potential risk of aortic and inferior vena cava displacement.[4]

Related studies have also reported that sustained pressure on the skin surface during prolonged surgical procedures predisposes patients to pressure-related injuries, including pressure ulcers and peripheral nerve injuries, with an incidence ranging from 5 to 66% among surgically treated patients.[5]

The Relton-Hall frame concentrates pressure on the anterior thoracic and abdominal walls at four specific points, thereby increasing the risk of cutaneous ulcer formation. This scenario may differ when using the Wilson frame, Andrews table, or the genupectoral position *(Figure 4)*, which allow more adequate exposure of the thoracic and lumbar segments. However, the use of these positioning devices does not eliminate the occurrence of intraoperative physiological alterations or postoperative complications.[6]

Spine surgeons must remain aware of intraoperative patient positioning to mitigate potentially harmful pressure on vulnerable structures, with particular attention to intra-abdominal organs. These conditions may systematically affect the patient, increasing the risk of intraoperative bleeding and ventilatory disturbances.[7]

Reports in the literature have described cases of sudden arrhythmia occurring after prone positioning when using the Jackson table, with thoracic compression considered the most likely underlying cause.[7]

Comparative analyses between the Jackson surgical table and the Wilson frame have shown that, although both devices require prone positioning and may increase intra-abdominal pressure, they are also associated with hemodynamic alterations, including pressure-dependent reductions in renal microvascular and macrovascular blood flow. Despite these findings, no significant differences in the incidence of acute kidney injury have been identified between positioning systems.[8]

In awake patients, hypotension induced by repositioning from the supine to the prone position is usually counteracted by baroreceptor activation and sympathetic nervous system responses. In contrast, surgically anesthetized patients exhibit reduced activation of these compensatory mechanisms following anesthetic induction, predisposing them to posture-related hypotension. This hemodynamic alteration may secondarily increase pressure within the thoracic and inferior vena cava systems, potentially triggering severe complications such as intraoperative hemorrhage, spinal cord ischemia, postoperative visual loss, and activation of the Bezold-Jarisch reflex.[9-11]

From a ventilatory standpoint, increased intra-abdominal pressure results in cephalad displacement of the diaphragm, leading to increased pulmonary vascular resistance and reduced respiratory compliance. These changes increase the risk of pulmonary atelectasis and are associated with variations in stroke volume, pulse pressure variation, and corrected flow time. Such physiological alterations appear to be attenuated when convex supports with minimal angulation are used during prone positioning.[12,13]

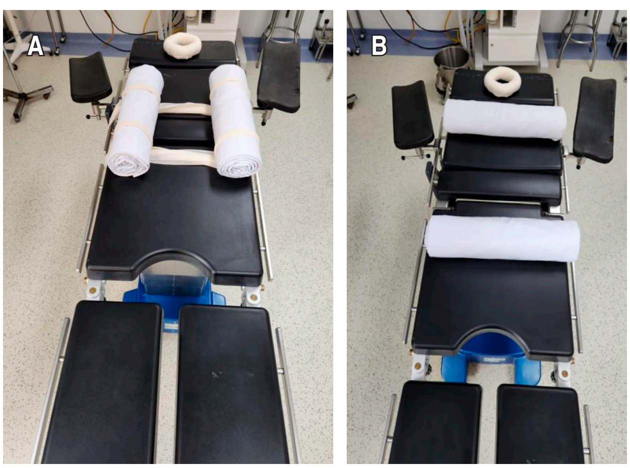

Figure 3: Surgical bolster positioning. **A)** Transverse bolsters. **B)** Longitudinal bolsters.

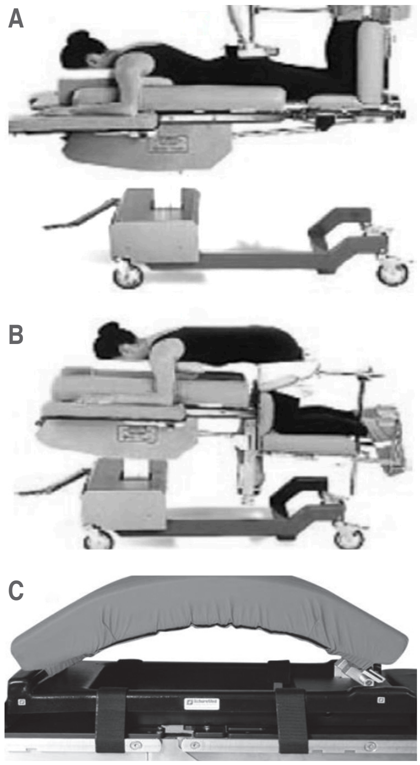

Figure 4: Surgical table positioning. **A)** Prone position. **B)** Genupectoral position. **C)** Wilson frame.
Images reproduced from: Mendoza-Popoca CU, Suárez-Morales M. Posterior spinal surgery and prone position. Is kneeling better for pulmonary mechanics? Rev Mex Anest. 2008; 31: 88-92.

MATERIAL AND METHODS

A randomized observational comparative case–control study was conducted in patients undergoing thoracolumbar surgical instrumentation between November 2022 and November 2023.

Inclusion criteria: a) Patients with vertebral fractures involving the thoracic and lumbosacral segments. b) Patients undergoing thoracolumbar spine instrumentation surgery in the prone position. c) Age $\geq$ 18 years. d) Both sexes.

Table 1: Patient registration.

Name	Age	Sex	Expedient	Diagnosis	Surgical plan	Roller positioning		Weight kg	Height m	BMI	Mean TA pre-QX
LRJ	20	Male	74212	FX L2 A1 N2 M1 ASIA C	Posterior thoracolumbar instrumentation T12-L4	Longitudinal	2	63	1.72	21.295	75.33
RAT	48	Male	78797	FX dislocation of L1 AO B1 N3 M1 ASIA B/T12 A1	Posterior instrumentation T11-L3 laminectomy L1	Longitudinal	2	80	1.7	27.682	86.67
DCV	28	Male	67280	FX flexocompression of L3 AO: A3 N3 M0 ASIA D	Posterior instrumentation of lumbar spine L1, L2, L4, L5, duroplasty	Longitudinal	2	65	1.63	24.465	104.00
MMV	66	Female	70231	DH L4-L5, L5-S1	Posterior stabilization L4-L5, L5-S1	Longitudinal	2	71.2	1.51	31.227	86.67
HRK	22	Male	74642	FX flexocompression L2	Posterior thoracolumbar instrumentation T12-L4	Longitudinal	2	66	1.81	20.146	112.67
HHA	52	Male	74887	FX T11 AO B2 N3 M0 ASIA A	Posterior thoracolumbar instrumentation T9-L1	Longitudinal	2	75	1.64	27.885	83.33
YVJ	66	Male	75489	FX T5, T6, T8	Posterior thoracic instrumentation T3-T9	Longitudinal	2	66	1.51	28.946	83.33
FML	24	Male	75562	FX LX T5, T6 ASIA A	Posterior thoracic instrumentation T3-T7	Longitudinal	2	55	1.63	20.701	93.33
AQP	53	Male	77134	FX flexocompression of L1 (L1: B2, N0, M1) / ASIA E	Posterior instrumentation T11-L3	Longitudinal	2	65	1.65	23.875	96.67
GBR	42	Male	77646	Flexocompression of T12 A1 N4 MO ASIA B	Long posterior instrumentation of T11-L2	Longitudinal	2	83	1.7	28.72	102.00
MMS	22	Male	78593	T11 AO A1 N0 M1/TLICS 7 pts/ASIA E	Long posterior instrumentation T8-L1	Longitudinal	2	68	1.66	24.677	70.00
JVR	23	Male	79421	FX of L1 AO A4 N0 M1 ASIA E	Long posterior instrumentation of T11-L3	Longitudinal	2	80	1.65	29.385	99.33
GJR	38	Male	78677	FX full burst of L4, AO: A4 NX M2 ASIA D	Short posterior instrumentation	Longitudinal	1	60	1.68	21.259	79.67
BPL	53	Male	6041	FX full burst L2 A2 B2 N0 M1 ASIA D	Posterior thoracolumbar instrumentation	Longitudinal	2	57	1.57	23.125	113.33
MCJ	19	Male	69006	FX T4 type A1, T5 type C and T6 type B2 N0 M2 ASIA D	T2-T8 transpedicular fixation	Longitudinal	2	70	1.74	23.121	76.67
AGO	37	Male	69830	FX of L2 A4 N0 M1 ASIA E	Posterior lumbar instrumentation L1-L3	Longitudinal	2	90	1.72	30.422	91.00
CCG	26	Male	70466	FX L2 A3-L3 A1 ASIA E	L2-L3 release + T11-L4 transpedicular fixation	Longitudinal	2	70	1.65	25.712	99.66
VBS	50	Female	71565	FX incomplete burst T12 AO A3 N0 M1 ASIA A	Posterior thoracolumbar instrumentation T10-L2	Longitudinal	2	78	1.52	33.76	80.00
FRJ	76	Male	2353	Lumbar spinal stenosis, L4-L5 and L5-S1 spondylolisthesis	Posterior lumbosacral instrumentation T11-S1	Transverse	1	52	1.48	23.74	104.33
ZMR	55	Male	19644	DH L5-S1	Posterior instrumentation of L3-S1 + L2 discectomy	Transverse	1	70	1.51	30.70	87.33
JOE	57	Male	52260	L4-L5 spondylolisthesis	Posterior instrumentation L4-L5	Transverse	1	100	1.84	29.537	83.33
JPL	61	Male	54565	QX vertebral destruction L2-L3	Posterior instrumentation + nerve decompression	Transverse	1	82	1.67	29.402	93.33
IHL	34	Male	63084	L4-L5, L5-S1 disc herniation	TLIFN L4-L5, L5-S1	Transverse	1	64	1.52	27.701	
ADR	24	Female	68444	FX incomplete burst of L1 AO A3 N0 M1 ASIA E	Posterior thoracolumbar instrumentation with eight polyaxial screws	Transverse	1	57.3	1.58	22.953	75.33
HLJ	21	Female	68849	Flexural compression fracture of L1 A1 N0 M0 ASIA E	Long posterior thoracolumbar instrumentation T12-L4	Transverse	1	50	1.48	22.827	100.00
JRM	61	Male	69066	FX in split of L1 A2 N0 M0 ASIA E	Posterior thoracolumbar instrumentation T12-L4	Transverse	1	73	1.6	28.516	94.67
GLV	43	Female	69320	FX T12 B2 N0 M2 ASIA E VACARD 4	Posterior thoracolumbar instrumentation T10-L2	Transverse	1	62.5	1.52	27.052	93.33

Continue of Table 1:

Name	Age	Sex	Expedient	Diagnosis	Surgical plan	Roller positioning		Weight kg	Height m	BMI	Mean TA pre-QX
MLG	51	Male	69677	FX LX of T1 AO C N4 M1 ASIA A	C5-T2 posterior instrumentation	Transverse	1	70	1.71	23.939	95.00
MTH	29	Male	69961	FX incomplete burst of T12 AO A3 N1 M1/ASIA C	Posterior thoracolumbar instrumentation T10-L1	Transverse	1	77.5	1.66	28.125	75.33
DMR	25	Male	70179	FX of C6 by burst	C4-T1 post-instrumentation	Transverse	1	72	1.65	26.446	71.33
MJA	37	Male	70483	FX LX T3-T4 C N4 M1 ASIA A	Posterior thoracolumbar instrumentation T2-T6	Transverse	1	65	1.55	27.055	101.33
MVJ	52	Male	70605	FX full burst of L1 AO B2 N3 M1 ASIA A	Posterior thoracolumbar instrumentation T11-L3	Transverse	1	62.5	1.64	23.238	84.33
TGO	28	Female	72213	L2 AO B2 N3 M1 ASIA C	Long column instrumentation	Transverse	1	62	1.55	25.806	67.00
ETR	43	Male	72381	FX L1 AO N4 M1 ASIA B burst	Posterior instrumentation T11-L3	Transverse	1	62.6	1.68	22.18	80.33
PTJ	26	Male	73555	FX full burst L1 AO A4 N0 M1 ASIA E	Posterior thoracolumbar instrumentation T11-L3	Transverse	1	85.6	1.81	26.129	103.67
OCF	46	Male	74257	FX T1 A1, T2 A2, T11 A3, L1 A1 N0 M1 ASIA E	Short posterior instrumentation at the T1-T3 level and long posterior instrumentation from T10 to L4	Transverse	1	83.5	1.66	30.302	94.33
LSM	31	Male	74938	FX flexocompression of T12 A1 N0 M1 ASIA E	Thoracolumbar instrumentation T10-L2	Transverse	1	79	1.79	24.656	90.00
CAM	44	Female	76863	FX L1 A1 NX M1 ASIA E	Posterior thoracic instrumentation T3-T6	Transverse	1	57	1.52	24.671	101.00
DJC	19	Male	77417	L1 AO: B1, NX, M1 ASIA not evaluable	Long posterior instrumentation T11-L2	Transverse	1	60.7	1.65	22.296	84.33
JCO	17	Male	77488	FX of L3 AO: B2 N3 M1/ ASIA C	Long posterior instrumentation of L1-L5	Transverse	1	60	1.64	22.308	73.00
CJR	55	Male	77850	FX of T7 AO: A4 N0 M1, TLICS 5, ASIA E	Thoracic instrumentation T5-T6 T8-T10	Transverse	1	68	1.59	26.898	85.67
JCV	39	Male	78347	FX of L2 AO A4 M1 N1 ASIA C	Thoracolumbar instrumentation with 10 polyaxial screws	Transverse	1	85	1.65	31.221	78.00
EAH	19	Male	78444	FX L2 AO: B1 - L1 AO: A2 N1 M1 ASIA E	Posterior thoracolumbar + T11-L4 instrumentation	Transverse	1	51	1.62	19.433	95.67
Median	39.1						1	68	1.65	25.968	90.00
Mean								69.32	1.63	26.006	89.52

Name	O_2 pre-QX	Hb pre-QX	Mean BP trans-QX	O_2 trans-QX	CO_2 trans-QX	O_2 maintenance	FiO_2	Mean BP post-QX	Plasma	With erythrocytes	Post-operative bleeding	Surgery duration	Premedication
LRJ	0.99	12.9	99.67	0.96	32	0.5	0.35	94.33	0	270	450	5	Tranexamic acid 1 g/IV
RAT	0.95	13	83.33	0.98	32	1	0.40	85	0	0	700	3	Tranexamic acid 1 g
DCV	0.91	15.8	92.33	0.96	31	2.5	0.56	109.33	0	0	400	4	NA
MMV	0.95	11.3	81.33	1.00	28	1	0.58	97.67	220	289	200	2	NA
HRK	0.91	12.4	89.33	0.99	29	0.5	0.40	86.33	150	540	1,000	4	Tranexamic acid 1 g
HHA	0.96	13.26	78.00	0.99	32	1	0.60	81.67	0	0	350	4	Tranexamic acid 1 g
YVJ	0.91	11.2	93.33	0.97	33	1	0.40	99.67	170	290	500	3	Tranexamic acid 1 g
FML	0.99	11.2	83.33	99.00	30	1	0.36	79.33	0	0	400	2	Tranexamic acid 1 g
AQP	0.98	15.6	86.67	0.99	30	0.5	0.20	83.33	0	0	230	2.3	NA
GBR	0.94	9.6	63.33	0.99	35	1	0.40	102.33	365	830	590	5	Tranexamic acid 1 g

Continue of Table 1:

Name	O_2 pre-QX	Hb pre-QX	Mean BP trans-QX	O_2 trans-QX	CO_2 trans-QX	O_2 maintenance	FiO_2	Mean BP post-QX	Plasma	With erythrocytes	Post-operative bleeding	Surgery duration	Premedication
MMS	0.93	15.3	88.00	1.00	31	2	0.60	91.00	0	0	500	3	Tranexamic acid 1 g
JVR	0.95	14.2	86.67	0.99	30	1	0.50	80.00	0	0	400	3	NA
GJR	0.95	11.9	66.67	0.99	32	1	0.50	69.67	0	0	100	3	NA
BPL	0.95	16.6	104.00	1.00	32	1	0.41	79	0	0	400	2.24	N0
MCJ	0.96	13.46	76.33	0.98	35	1	0.39	83.33	0	0	1,100	4	Tranexamic acid 1 g/IV
AGO	0.94	14.88	86.67	0.98	35	1.5	0.50	73	0	0	150	3	N0
CCG	0.95	14.65	82.66	0.99	31	1.5	0.40	89.33	0	0	110	5	Tranexamic acid 1 g/IV
VBS	0.98	12.46	88.00	0.99	30	1	0.60	83.33	0	0	100	3.3	NA
FRJ	0.94	11.8	76.67	0.98	32	2	0.46	72.00	0	565	1,010	6	Tranexamic acid 1 g/IV + albumin 2 jars
ZMR	0.96	12.9	64.00	1.00	38	1	0.50	71.33	175	295	600	4	Tranexamic acid 1 g
JOE	0.94	15.6	82.67	0.98	28	2	0.40	86.67	NA	0	500	4	NA
JPL	0.95	17	101.67	0.98	33	0.5	0.50	72.33	230	280	1,000	3	Tranexamic acid 1 g
IHL	0.97	14.81	95.00	0.97	31	1	0.66	83	185	305	1,100	3	N0
ADR	0.93	13.7	86.00	0.96	31	0.5	0.54	90.33	0	0	400	4	N0
HLJ	0.98	13.8	83.33	1.00	33	1	0.45	76.67	0	0	850	4	Tranexamic acid 1 g
JRM	0.95	14.71	68.67	0.98	32	0.5	0.50	74.33	0	0	350	4	NA
GLV	0.92	15.01	112.00	0.93	31	1	0.58	86.00	0	0	300	2.2	Tranexamic acid 1 g
MLG	0.96	13.6	111.00	0.96	30	1	0.50	81.67	220	285	800	5	Tranexamic acid 1 g/IV + albumin 1 jar
MTH	0.92	16.8	86.67	0.99	29	0.5	0.45	96.33	0	0	900	3.3	N0
DMR	0.99	9.17	62.00	0.98	34	2	0.60	69.33	205	870	850	3.2	Tranexamic acid 100 mg
MJA	0.94	14.65	99.00	0.99	31	1	0.50	72.33	0	0	350	3.4	NA
MVJ	0.98	13.3	80.23	0.98	30	0.8	0.50	110.67	0	0	710	4	N0
TGO	0.92	10.7	88.00	1.00	36	2	0.56	90.00	0	0	800	3.3	Tranexamic acid 1 g/IV
ETR	0.94	11.6	80.33	0.97	32	0.5	48.00	93.33	190	250	800	4.2	Tranexamic acid 1 g + albumin 1 jar
PTJ	1.00	14.22	73.67	0.99	37	1	0.50	79.33	0	0	800	3.3	Tranexamic acid 1 g/IV
OCF	0.89	13.5	99.00	1.00	31	2	0.66	80.00	175	280	550	4	Albumin 2 jars
LSM	0.96	16.17	76.67	0.96	33	1	0.50	80.00	0	0	850	3	NA
CAM	0.98	9.4	80.67	1.00	32	2	0.40	73.33	0	0	300	4	NA
DJC	0.95	11.6	88.33	0.97	35	1	0.60	92.33	0	0	500	4	Tranexamic acid 1 g
JCO	0.95	12.9	97.33	0.99	33	2	0.50	100.00	0	0	350	4	Tranexamic acid 1 g
CJR	0.95	11.2	80.00	0.95	37	3	0.40	89.67	200	250	350	3	Tranexamic acid 1 g
JCV	0.90	13.8	90.67	0.98	30	1	0.50	81.33	0	0	500	4	Tranexamic acid 1 g
EAH	0.96	13.7	73.67	0.97	40	1	0.68	83.33	0	0	680	3	Tranexamic acid 1 g
Median	0.95	13.55	84.67	0.99	32	1	0.5	83.33	0	0	500	3.35	
Mean	0.95	13.39	84.93	3.32	32.26	1.21	1.62	84.74	60.61	126.88	557.86	3.54	

BMI = body mass index. DH = disc herniation. FX = fracture. Hb = hemoglobin. IV = intravenous. LX = lumbar. NA = not applicable. NX = neurological. BP = blood pressure. TLICS = toracolumbar injury clasification and severity score. TLIF = transforaminal lumbar interbody fusion. QX = surgical.

Exclusion criteria: a) Patients with a prior diagnosis of cardiovascular or pulmonary disease. b) Patients requiring anterior instrumentation or procedures involving spinal segments other than the thoracolumbar or lumbosacral region.

A non-probabilistic consecutive case sampling technique was used. Sample size calculation was performed using the formula for comparative observational studies described by Hulley et al., considering the proportion of patients presenting thoracic and lumbar spine fractures with an expected total margin of error of ± 0.2.

Patients were stratified according to the spinal segment involved and the type of instrumentation performed. A comprehensive registry of collected variables was created *(Table 1)*, which included parameters recorded during the preoperative, intraoperative, and postoperative periods.

The analysis was conducted in three phases:

Sensitivity phase. This phase was based on the evaluation performed by five fellowship-trained orthopedic spine surgeons affiliated with this institution. Hemodynamic and ventilatory changes were assessed in the preoperative, intraoperative, and postoperative periods, using 15 cm high fabric positioning rolls between the surgical table and the patient (longitudinal with anatomical reference at the superior anterior iliac spine to the outer third of the clavicle vs transverse which are placed parallel at the level of the fifth intercostal space, and over both iliac crests respectively exceeding 5 cm the edge on each side of the patient's body) as the primary reference. Postoperative records and anesthesiology charts were reviewed.

Consistency phase. To analyze ventilatory and hemodynamic changes throughout the surgical period, standard monitoring parameters recorded by the anesthesiology and nursing teams were utilized. For comparative purposes, identical parameters were obtained at admission to the operating room and again in the post-anesthesia care unit.

Statistical analysis. Data were recorded in an Excel database and subsequently analyzed using IBM SPSS Statistics version 25. Descriptive statistics were reported using measures of central tendency and dispersion. Statistical significance was defined as a p value < 0.05. Correlation validity was assessed by measuring patient variability using the Pearson correlation coefficient.

RESULTS

A total of 43 patients undergoing posterior thoracic and lumbosacral spine surgery were evaluated over a one-year period in the spine surgery department. The cohort consisted of 36 male and 7 female patients, with a mean age of 39.1 ± 21.1 years. 18 patients were positioned using a longitudinal bolster configuration, whereas 25 patients were positioned using transverse bolsters.

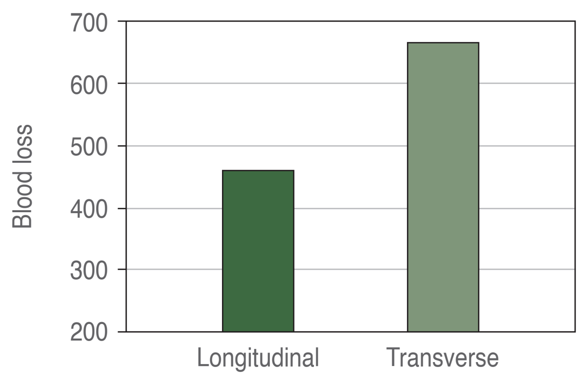

Figure 5: Intraoperative blood loss according to bolster positioning.
The figure shows the mean intraoperative blood loss in patients undergoing posterior thoracolumbar spine surgery with longitudinal (blue) and transverse (orange) bolster positioning, with mean values of 460 mL and 668 mL, respectively.

Table 2: Correlations (N = 43).

			Bolsters	Blood loss
Spearman's Rho	Bolsters	Correlation coefficient	1.000	0.341*
		Sig. (two-tailed)		0.025
	Blood loss	Correlation coefficient	0.341*	1.000
		Sig. (two-tailed)	0.025	

* Correlation is significant at the 0.05 level (two-tailed).

Table 3: Correlations (N = 43).

			Bolsters	Blood loss
Spearman's Rho	Bolsters	Correlation coefficient	1.000	0.663*
		Sig. (two-tailed)		0.00
	Tranexamic acid	Correlation coefficient	0.663*	1.000
		Sig. (two-tailed)	0.00	

* Correlation is significant at the 0.01 level (two-tailed).

The analysis demonstrated a p value of 0.025 (< 0.05), leading to rejection of the null hypothesis and acceptance of the research hypothesis. These findings provide evidence of an association between bolster configuration (longitudinal vs transverse) and intraoperative blood loss. The correlation coefficient was 0.341, indicating a low positive correlation between these variables *(Table 2)*.

These findings indicate that hemodynamic changes do occur between longitudinal and transverse bolster positioning in patients undergoing posterior thoracolumbar surgical approaches, with greater intraoperative blood loss observed in the transverse bolster configuration compared with the longitudinal configuration *(Figure 5)*.

As this is a public institution with limited economic resources, the routine application of tranexamic acid is not standardized. Therefore, we report results in the group with and without its use, correlating the use of longitudinal and transverse rolls as the main objective of the study. The calculated p-value was < 0.01, with a Spearman's rho correlation coefficient of 0.663, indicating a strong direct association between intraoperative blood loss and the administration of tranexamic acid *(Table 3)*.

In conclusion, it can be stated with 99% confidence that there is a strong positive association between the administration of tranexamic acid and a reduction in intraoperative blood loss as an independent variable. This association, when combined with the longitudinal placement of rolls, significantly reduces bleeding in patients undergoing thoracolumbar spine surgery *(Figure 6)*.

A p value of 0.030 (< 0.05) was obtained, leading to rejection of the null hypothesis and acceptance of the research hypothesis. These results provide evidence of an association between bolster configuration (longitudinal vs transverse) and inspiratory oxygen fraction (FiO_2), with a correlation coefficient of 0.331, indicating a low positive correlation between these variables *(Table 4)*.

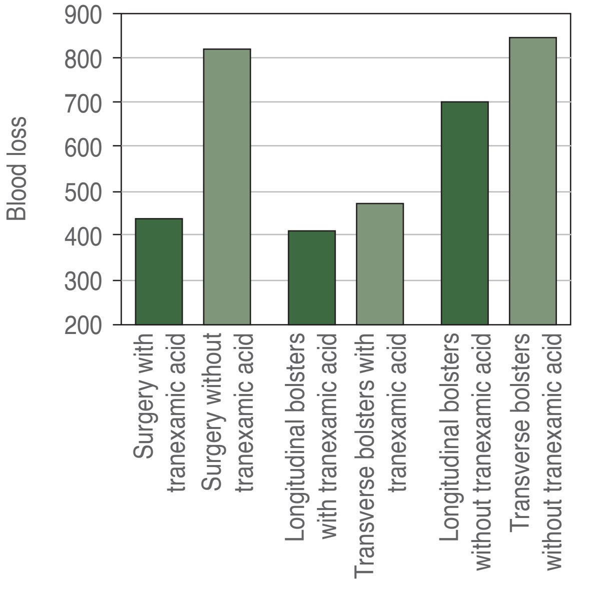

Figure 6: Intraoperative blood loss according to tranexamic acid administration.
The figure illustrates the mean intraoperative blood loss in patients who received tranexamic acid premedication (blue) compared with those who did not receive tranexamic acid (orange). Greater blood loss was observed in patients who did not receive tranexamic acid, with a mean blood loss of 820 mL compared with 439.2 mL in patients who did receive tranexamic acid.

These findings indicate that ventilatory changes occur according to bolster positioning in patients undergoing posterior thoracolumbar surgical approaches, with higher intraoperative oxygen requirements observed in patients positioned with transverse bolsters compared with those positioned with longitudinal bolsters *(Figure 7)*.

A p value > 0.05 was obtained, indicating no significant association between bolster configuration and preoperative, intraoperative, or postoperative mean arterial pressure *(Table 5)*.

DISCUSSION

Based on a review of the literature, no comparable studies were identified that would allow direct positive or negative comparison of our findings. The study population comprised 43 patients (36 male and seven female), with a mean age of 39.1 ± 21.1 years. Of these, 18 patients were positioned using longitudinal bolsters and 25 using transverse bolsters. Hemodynamic and ventilatory changes associated with repositioning from the supine to the prone position were analyzed.

The differences observed were statistically significant, as demonstrated by Spearman's rho correlation analysis ($p < 0.05$), showing reduced intraoperative blood loss in patients positioned with longitudinal bolsters compared with transverse bolsters, as well as lower oxygen requirements, positively improving the combination of longitudinal rolling with the use of tranexamic acid.

The mean body mass index in patients positioned with transverse bolsters was 25.7, compared with 26.1 in those positioned with longitudinal bolsters; however, no statistically significant association was identified between body mass index and the final outcomes of our study, as a limitation, we found that this may vary in higher degrees of obesity or in morbid obesity since the positioners would have to change the height and have limitations in releasing intra-abdominal pressure secondarily.

Tranexamic acid use was analyzed, both independently and in combination with a bolster configuration, this is a limitation and could potentially bias our study since we lack the financial resources to apply it uniformly to all our patients. In other words, intraoperative blood loss was evaluated regardless of bolster positioning, as well as specifically in patients who received tranexamic acid while controlling for longitudinal versus transverse bolster placement. This approach allowed a more precise assessment of the additive effect of tranexamic acid on intraoperative bleeding reduction.

Important limitations of this study include the fact that it is only one reference center, the uncontrolled variable of the use of tranexamic acid in a unified manner in all cases, and secondarily, that it is subdivided into study groups depending on the body mass index, which is a main factor in intra-abdominal pressure and possible ventilatory and hemodynamic complications.

CONCLUSIONS

Patients undergoing posterior thoracolumbar spine surgery with longitudinal bolster positioning experienced lower intraoperative blood loss and

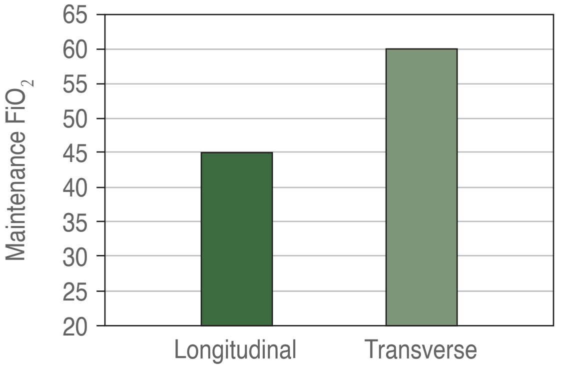

Figure 7: Intraoperative inspiratory oxygen fraction (FiO_2) according to bolster positioning.
The figure shows the mean FiO_2 in patients undergoing posterior thoracolumbar spine surgery, comparing longitudinal (blue) and transverse (orange) bolster positioning, with mean values of 45 and 52%, respectively.

Table 4: Correlations (N = 43).

			Bolsters	Intraoperative CO_2	FiO_2
Spearman's Rho	Bolsters	Correlation coefficient	1.000	0.200	0.331
		Sig. (two-tailed)		0.199	0.030*
	Intraoperative CO_2	Correlation coefficient	0.200	1.000	0.061
		Sig. (two-tailed)	0.199		0.696
	FiO_2	Correlation coefficient	0.331	0.061	1.000
		Sig. (two-tailed)	0.030	0.696	

* Correlation is significant at the 0.05 level (two-tailed).

Table 5: Correlations (N = 43).

			Bolsters	Preoperative MAP	Postoperative MAP
Spearman's Rho	Bolsters	Correlation coefficient	1.000	−0.076	−0.036
		Sig. (bilateral)		0.628	0.818
	Preoperative MAP	Correlation coefficient	−0.076	1.000	0.030
		Sig. (two-tailed)	0.628		0.849
	Postoperative MAP	Correlation coefficient	−0.036	0.030	1.000
		Sig. (two-tailed)	0.818	0.849	

Spearman correlation analysis between bolster positioning and mean arterial pressure (MAP).

reduced oxygen requirements. Additionally, patients who received tranexamic acid demonstrated decreased intraoperative bleeding, with the greatest reduction observed when tranexamic acid administration was combined with longitudinal bolster positioning.

This study has limitations due to its single-center design and the lack of standardized routine use of tranexamic acid due to cost constraints. However, it represents one of the first analyses to address this cost-effective intraoperative positioning strategy, commonly used in public and private institutions in Mexico. Therefore, it sets a relevant precedent for future national and international research conducted in spinal surgery centers, suggesting the expansion of subgroups with different body mass indices to observe whether the results become less significant as abdominal circumference increases.

REFERENCES

1. Schonauer C, Bocchetti A, Barbagallo G, Albanese V, Moraci A. Positioning on surgical table. Eur Spine J. 2004; 13: S50-55. doi: 10.1007/s00586-004-0728-y.
2. Yadav M, Reddy EP, Sharma A, Kulkarni DK, Gopinath R. The Effect of position on PaCO2 and PETCO2 in patients undergoing cervical spine surgery in supine and prone position. J Neurosurg Anesthesiol. 2017; 29: 298-303. doi: 10.1097/ANA.0000000000000322.
3. Jain M, Lal J, Aggrawal D, Sharma J, Singh AK, Bansal T. A Study to evaluate changes in modified mallampati class in patients undergoing spine surgery in prone position. Cureus. 2022; 14: e25767. doi: 10.7759/cureus.25767.
4. Plataniotis N, Evangelopoulos DS, Katzouraki G, Pneumaticos S. The effect of patient positioning on the relative position of the aorta to the thoracic spine. Eur Spine J. 2019; 28: 477-483. doi: 10.1007/s00586-018-5812-9.
5. Lin S, Hey HWD, Lau ETC, Tan KA, Thambiah JS, Lau LL, et al. Prevalence and predictors of pressure injuries from spine surgery in the prone position: do body morphological changes during deformity correction increase the risks? Spine (Phila Pa 1976). 2017; 42: 1730-1736.
6. Shriver MF, Zeer V, Alentado VJ, Mroz TE, Benzel EC, Steinmetz MP. Lumbar spine surgery positioning complications: a systematic review. Neurosurg Focus. 2015; 39: E16. doi: 10.3171/2015.7.FOCUS15268.
7. Kim JH, Kim S, Yu T, Yang WS, Hong SW. Sudden arrhythmia in the prone position during spinal surgery: a case report. Medicine (Baltimore). 2022; 101: e30137. doi: 10.1097/MD.0000000000030137.
8. Jin SJ, Park YS, Kim SH, Kim D, Shim WH, Jang DM, et al. Effect of prone positional apparatus on the occurrence of acute kidney injury after spine surgery. World Neurosurg. 2019; 128: e597-e602. doi: 10.1016/j.wneu.2019.04.216.
9. Yoon HK, Lee HC, Chung J, Park HP. Predictive factors for hypotension associated with supine-to-prone positional change in patients undergoing spine surgery. J Neurosurg Anesthesiol. 2020; 32: 140-146. doi: 10.1097/ANA.0000000000000565.
10. Poon KS, Wu KC, Chen CC, Fung ST, Lau AW, Huang CC, et al. Hemodynamic changes during spinal surgery in the prone position. Acta Anaesthesiol Taiwan. 2008; 46: 57-60. doi: 10.1016/S1875-4597(08)60026-0.
11. Mahajan S, Swami AC, Kumar A. Cardiovascular changes and lumbar spine surgery: a neglected entity. Asian J Neurosurg. 2019; 14: 1253-1255. doi: 10.4103/ajns.AJNS_224_19.
12. Yang SY, Shim JK, Song Y, Seo SJ, Kwak YL. Validation of pulse pressure variation and corrected flow time as predictors of fluid responsiveness in patients in the prone position. Br J Anaesth. 2013; 110: 713-720. doi: 10.1093/bja/aes475.
13. Bible JE, Mirza M, Knaub MA. Blood-loss management in spine surgery. J Am Acad of Orthop Surg. 2018; 26: 35-44. doi: 10.5435/jaaos-d-16-00184.

Conflict of interests: the authors declare no conflict of interests.