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Incidence of temporary intraoperative iliac artery occlusion during anterior spinal surgery

Matthew H. Claydon, MB, BS, BMedSci, FRACS[a,c], Dean T. Biddau, BBiomedSc[a,b,c], Alexander N. Claydon[a], Jordan P. Laggoune, BSc (Hons)[a], Gregory M. Malham, BSc, MB, ChB, DMed, FRACS[a,c,d,e,f,*]

[a] Neuroscience Institute, Epworth Hospital, Richmond, Melbourne, Australia
[b] School of Biomedical Science, Faculty of Health, Queensland University of Technology, Brisbane, Queensland, Australia
[c] Spine Surgery Research Foundation, Richmond, Victoria, Australia
[d] Spine Surgery Research, Department of Health Science and Biostastics, Swinburne University of Technology, Melbourne, Victoria, Australia
[e] Department of Medicine and Surgery, University of Melbourne, Parkville, Victoria, Australia
[f] School of Health Science and Biomedine, RMIT University, Melbourne, Victoria, Australia

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ABSTRACT

Background: Thromboembolic complications in anterior lumbar spinal surgery can rarely result in limb loss. Iliac vessel retraction can temporarily occlude the iliac artery risking thromboembolic sequelae. Studies estimate the incidence of iliac artery thrombosis at 0.45%. Brief intraoperative heparinization can potentially mitigate this risk. We aim to quantify the incidence of temporary iliac artery occlusion (TIAO) and examine its association with potential risk factors (sex, BMI, target disc level, and type of prosthesis).

Methods: Retrospective analysis of consecutive patients undergoing anterior lumbar spinal surgery by a single vascular surgeon and 5 spinal neurosurgeons between 2009 and 2022. Patients underwent single or double-level total disc replacement (TDR); single, double, or triple-level anterior lumbar interbody fusion (ALIF); or hybrid procedure (combined cranial TDR and caudal ALIF). A pulse oximeter monitored bilateral second toes perfusion. Loss of the waveform, combined with a nonpalpable external iliac artery pulse distal to the retractors was defined as TIAO of the ipsilateral artery. Heparin was administered if TIAO developed.

Results: Of 605 patients (318 males, 287 females), TIAO occurred in 176 patients (29.1%). TIAO occurred in 13.5% of the 377 patients who underwent single or multilevel ALIF and in 42.7% of the 110 patients who underwent single or multilevel TDR (p=.004). In single-level surgery at L5/S1, TIAO occurred in 3.1% of patients. In single-level surgery at L4/5, TIAO occurred in 65.2% of patients overall; the rate was higher for TDR than for ALIF (74.6% vs. 48.5%; p=.01). The TIAO rate was 44.3% in multilevel procedures and 66.1% in hybrid procedures. No patient developed postoperative thrombotic iliac artery occlusion or embolic complications.

Conclusions: TIAO occurred frequently during anterior lumbar exposure (29%). Anterior spinal exposure at L4/5 had a high incidence of TIAO, particularly for TDR, in contrast to L5/S1.

Introduction

Anterior exposure for lumbar spinal surgery has become increasingly common over the past 2 decades, enabling total disc replacement (TDR) and interbody fusion with a wider footprint prosthesis, which are not possible through a posterior approach [1]. However, anterior exposure requires dissection and retraction of the major aortoiliac arteries. Retraction of iliac vessels can temporarily occlude the iliac artery, disturbing blood flow and potentially resulting in thrombosis or embolic sequelae [2]. Temporary iliac artery occlusion (TIAO) is analogous to applying a vascular clamp to the vessel, which usually does not damage a disease-free vessel. TIAO is not an arterial injury or thrombosis and usually is relieved with the release of the retraction. However, if the vessel has pre-existing disease (eg, atherosclerosis-related plaque and calcification, aneurysmal degeneration) then arterial thrombosis and permanent blockage of the artery or embolic sequelae

FDA device/drug status: Not applicable.

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* Corresponding author. Neuroscience Institute, Epworth Hospital, Suite 8.3, 89 Bridge Road, Richmond, Melbourne, VIC 3121, Australia.
E-mail address: gmalham@bigpond.net.au (G.M. Malham).

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may occur. This can also occur if temporary occlusion of a disease-free vessel is prolonged, especially in the absence of anticoagulant.

Females often have smaller arteries [3], which may render them particularly vulnerable to iliac artery compression and occlusion. Overweight and obese patients require greater retractive forces to achieve adequate exposure, which may likewise result in a higher rate of arterial compression. Arterial thromboembolic complications of anterior lumbar spinal surgery occur infrequently [4], but in rare instances, they can result in limb loss.

Unrecognized acute ischemia because of iliac artery occlusion secondary to thrombosis or dissection can result in lower extremity necrosis and may ultimately lead to amputation. Thrombosis of the iliac artery usually requires a major vascular procedure involving arteriotomy, thrombectomy, and arterial repair, which itself may lead to major complications, such as occlusion, dissection, and bleeding. Lower limb emboli can cause pain and digital necrosis. Proximal emboli (of the femoral, popliteal, or tibial arteries) can frequently be retrieved via open thrombectomy. Distal emboli ("trash") are often irretrievable, either through surgical or endovascular techniques. Thrombolysis is contraindicated postoperatively. Thus, these emboli are effectively permanent [5].

There have been multiple case reports of iliac artery thrombosis causing ischemia after anterior lumbar spinal surgery. Only 1 large case series has been reported, which found a 0.45% estimated incidence of postoperative iliac artery thrombosis requiring vascular intervention among 629 patients [4]. Brief intraoperative heparinization has been demonstrated to potentially mitigate thromboembolic complications [6].

Oxygen saturation meters are an inexpensive, noninvasive, readily available, and validated modality to monitor and detect a reduction in lower limb perfusion [7]. Infrared oxygen saturation meters (ie, pulse oximeters) can sensitively detect blood flow pulsatility, which is displayed as a waveform [7]. TIAO can be accurately detected by loss of the pulse oximeter signal [8] combined with loss of a previously palpable pulse distal to the retractors. When these 2 criteria are met, the artery is clinically occluded. In this study, we quantified the incidence of TIAO during anterior lumbar exposure for spinal surgery, as assessed by pulse oximetry and pulse palpation. We also examined the association between TIAO and various potential risk factors, including sex, body mass index (BMI), target disc level, and type of spinal prosthesis used.

Materials and methods

Study design and patients

This study is a retrospective analysis of a prospectively collected database of consecutive patients undergoing anterior lumbar spinal surgery by a single vascular surgeon and 5 neurosurgeons between January 2009 and August 2022. Institutional Review Board approval was obtained (EH2023-1008).

We recorded demographic data for all patients, including BMI when available. The 5 neurosurgeons used the same disc space preparation and similar procedures for implantation of the interbody and TDR prostheses, which were based on the manufacturers' instructions. The procedures performed were single or double-level TDR; single, double, or triple-level anterior lumbar interbody fusion (ALIF); or a hybrid procedure (combination of cranial TDR and caudal ALIF[s]).

Indications for surgery were degenerative disc disease, including disc prolapse, foraminal stenosis, discogenic pain confirmed on discography, or grade I-II spondylolisthesis (degenerative or isthmic). Patients were not included in this study if they met any of the following criteria: more than 3-level disc disease, Grades 3 to 4 spondylolisthesis, significant iliac artery pathology (eg, heavy calcification, aneurysmal disease, severe stenosing atherosclerotic disease), morbid obesity (BMI >40 kg/m^2), previous complex or extensive retroperitoneal surgery, or abdominopelvic radiotherapy.

Patient management

All patients underwent preoperative duplex ultrasonography of the abdominal and iliac major vessels to exclude vascular anomalies, severe atheromatous disease, and calcification. If the duplex scan showed an abnormality or was difficult to visualize, computed tomography angiography (CTA) was performed.

Intraoperatively, a right lower transverse muscle-sparing incision and retroperitoneal approach were used to access the L5/S1 level. This level was approached between the iliac vascular bundles, and the median sacral vessels were usually ligated and divided. A midline lower abdominal incision and left-sided retroperitoneal approach were used to access the L4/5 level or multiple levels.

A table-mounted abdominal retractor was used in combination with vessel retraction pins. These pins were driven into the vertebral bodies to help restrain the iliac vessels. Use of vessel retraction pins combined with a narrow table-mounted retractor blade effectively spread the retractive force applied to the vessels to reduce the likelihood of vessel kinking. An added benefit was that the combination allowed the force applied to the vessels to be divorced from the force applied to retract the other intraabdominal contents. For the L4/5 and L3/4 levels, the left common iliac vein and artery were mobilized and retracted, and the left ascending lumbar vein was usually dissected out, ligated, and then divided.

Patients undergoing ALIF received either an integrated cage-plate device or separate cage and plate constructs. All patients undergoing TDR received a keeled anterior arthroplasty device. For those undergoing a hybrid procedure, the construct was a combination of TDR and ALIF devices at multiple levels.

A pulse oximeter was placed on the first or second toes bilaterally, and the waveform on each oximeter was monitored throughout the surgery. Complete loss of a previously good volume baseline waveform combined with the loss of a previously palpable external iliac artery pulse distal to the retractors was defined as occlusion of the ipsilateral iliac artery. When occlusion was detected, the initial step was to attempt to reduce the force exerted onto the vessels by the retractor blade to return a waveform signal. Placing vessel retraction pins in addition to the retractor blades allowed the retractive force to be spread over a broader area and reduced vessel kinking, which returned the signals in some cases. However, it was not always possible to provide adequate exposure without the loss of the waveform and pulse. When TIAO was detected, heparin (heparin sulfate; Baxter, IL) was administered at 50–75 units/kg [6]. Return of the saturation meter waveform and palpable pulse was confirmed on the release of retraction, and the heparin was then reversed with protamine sulfate (Sigma-Aldrich, Inc., MO). Pedal pulses were checked pre and postoperatively in all cases by the vascular surgeon to assess patency of proximal arteries.

Thromboembolic deterrent stockings (TED antiembolism stockings; Covidien, Dublin, Ireland) and sequential compression devices (SCDs) were used intraoperatively in all patients. Postoperatively, the TED stockings were continued in all patients, and the SCDs were continued in those considered at high risk for venous thromboembolism (eg, previous deep vein thrombosis [DVT] or pulmonary embolism). Prophylactic enoxaparin (Clexane; Sanofi-Aventis, Paris, France) was begun postoperatively in all patients.

Statistical analysis

Data are presented as mean ± standard deviation or as frequencies and percentages. Two-sided p-values were generated to evaluate and compare the incidence of TIAO for operative levels, prosthesis, and BMI. p-values were compared using a 2-sided *t*-test or chi-square test, as appropriate. p-values <.05 were considered statistically significant.

Table 1
Patient and surgery characteristics.

Patient demographics	Value
Total number	605
Age, years, range (mean±SD)	17–86 (46±13)
Male, n (%)	318 (53)
Female, n (%)	287 (47)
BMI, kg/m^2, mean±SD	27±6
Type and level of surgery	**No. of patients**
ALIF	377
Single-level	314
L5/S1	281
L4/5	33
Two-level	59
L5/S1+L4/5	54
L4/5+L3/4	3
L5/S1+S1/2	2
Three-level	4
L3/4+L4/5+L5/S1	4
TDR	110
Single-level	105
L5/S1	44
L4/5	59
L3/4	2
Two-level	5
L5/S1+L4/5	2
L4/5+L3/4	3
Hybrid procedure	118
Two-level	116
L5/S1+L4/5	110
L4/5+L3/4	6
Three-level	2
L5/S1+L4/5+L3/4	2

ALIF, anterior lumbar interbody fusion; BMI, body mass index; SD, standard deviation; TDR, total disc replacement.

Binary logistic regression was performed at a univariable level to evaluate the relationship between TIAO and sex. Univariable covariates of p<.20 were used to assess significance of the univariate regression analyses. R^2 and adjusted R values were generated to assess regression correlations between TIAO and sex.

All analyses were performed using Stata MP/14.0 (StataCorp, College Station, TX) and Excel (Microsoft, Seattle, WA).

Results

The study cohort consisted of 605 patients (318 males, 287 females). Table 1 shows the patient demographic information and the types and levels of procedures. TIAO occurred in 176 patients, yielding an overall rate of 29.1% (Table 2). There was no statistically significant difference in the rate of TIAO between females (n=93; 32.4%) than in males (n=83; 26.1%) (p=.08) (Table 3). Saturation meter waveform signal and palpable pulse returned on the release of the retraction in all cases. There were no cases of permanent arterial thrombosis or embolic complications in this series.

TIAO during single-level procedures

L5/S1

In 325 of the 605 patients, surgery (either ALIF or TDR) was performed at only the L5/S1 level. TIAO occurred in 10 of these patients, for an overall rate of 3.1%. Of the 281 patients who underwent ALIF at L5/S1, TIAO occurred in 8 patients (2.8%) with no significant difference between males and females (p=.67). Of the 44 patients who underwent TDR at L5/S1, TIAO occurred in 2 patients (4.5%). TIAO occurred in none of the 24 males and 2 of the 20 females; because of the low number of patients with TIAO, statistical analysis was not performed to compare sexes. For single-level surgery at L5/S1, TIAO rates did not differ significantly between TDR and ALIF (p=.97).

L4/5

In 92 of the 605 patients, surgery (either ALIF or TDR) was performed at only the L4/5 level. TIAO occurred in 60 of these patients, for an overall rate of 65.2%. Of the 33 patients who underwent ALIF at L4/5, TIAO occurred in 16 patients (48.5%). TIAO rates were not significantly different between males and females (males vs. females: 6/9 [66.7%] vs. 10/24 [41.7%]; p=.09). Of the 59 patients who underwent TDR at L4/5, TIAO occurred in 44 patients (74.6%). TIAO rates were not significantly different between males and females (males vs. females: 19/28 [67.9%] vs. 25/31 [80.6%]; p=.27). For single-level surgery at L4/5, the rate of TIAO was significantly higher for TDR than for ALIF (74.6% vs. 48.5%; p=.01).

L3/4

Two patients underwent surgery at only the L3/4 level. Both patients underwent TDR, and neither developed TIAO.

L4/5 versus L5/S1

Overall, 60 of the 92 patients (67%) who underwent surgery at L4/5 developed TIAO. By contrast, only 10 of the 325 patients (3%) who underwent surgery at L5/S1 developed TIAO. The difference in TIAO rates between operative levels was highly statistically significant (p=.002).

TIAO during multilevel surgery

Multilevel surgery was performed in 186 of the 605 patients, including 2 or 3-level ALIF, 2-level TDR, or hybrid surgery. Exposure of the

Table 2
Incidence of intraoperative temporary iliac artery occlusion.

Surgery	Operative level(s)	Total, n	Total TIAO, n (%)	Total males, n	Males with TIAO, n (%)	Total females, n	Females with TIAO, n (%)
All patients	-	605	176 (29)	318	83 (26)	287	93 (32)
ALIF	L3/4+L4/5	3	0	1	0	2	0
	L4/5	33	16 (48)	9	6 (67)	24	10 (42)
	L5/S1	281	8 (3)	159	5 (3)	122	3 (3)
	L3/4+L4/5+L5/1	4	2 (50)	2	1 (50)	2	1 (50)
	L5/S1+S1/2	2	0	1	0	1	0
	L4/5+L5/1	54	25 (46)	27	13 (48)	27	12 (44)
TDR	L3/4	2	0	2	0	0	0
	L4/5	59	44 (75)	28	19 (68)	31	25 (81)
	L3/4+L4/5	3	1 (33)	1	1 (100)	2	0
	L4/5+L5/1	2	0	2	0	0	0
	L5/S1	44	2 (5)	24	0	20	2 (10)
Hybrid	L3/4+L4/5	6	4 (67)	2	2 (100)	4	2 (50)
	L3/4+L4/5+L5/S1	2	2 (100)	2	2 (100)	0	0
	L4/5+L5/S1	110	72 (65)	58	34 (59)	52	38 (73)

ALIF, anterior lumbar interbody fusion; TDR, total disc replacement; TIAO, temporary iliac artery occlusion.

Table 3
Comparisons of intraoperative temporary iliac artery occlusion rates between various cohorts.

Cohort	Total, n	TIAO, n	TIAO, %	p-value	Cohort	Total, n	TIAO, n	TIAO, %	p-value
Male	318	83	26	.08					
Female	287	93	32		Multilevel surgery	186	108	58	
L5/S1	325	10	3		Multilevel ALIF	61	27	44	
ALIF	281	8	3		Male	30	14	47	.85
Male	159	5	3	.67	Female	31	13	42	
Female	122	3	2						
					Multilevel TDR	5	1	20	
TDR	44	2	5		Male	3	1	33	N/A
Male	24	0	0	N/A	Female	2	0	0	
Female	20	2	10						
					Multilevel hybrid	118	78	66	
L5/S1 ALIF	281	16	6	.97	Male	62	38	61	.66
L5/S1 TDR	44	3	7		Female	56	40	71	
L4/5	92	60	65		Body mass index				
ALIF	33	16	49		BMI=18–24 kg/m^2	122	34	28	.76
Male	9	6	67	.09	BMI=25–30 kg/m^2	266	66	29	
Female	24	10	42		BMI=31–40 kg/m^2	77	18	23	
TDR	59	44	75		ALIF vs. TDR				
Male	28	19	68	.27	ALIF	377	51	14	.004
Female	31	25	81		TDR	110	47	48	
L4/5 ALIF	33	16	48	.01	L4/5 ALIF	33	16	49	.001
L4/5 TDR	59	44	75		L5/S1 ALIF	281	8	3	
L5/S1	325	10	3	.002	L4/5 TDR	59	44	68	.001
L4/5	92	60	67		L5/S1 TDR	44	2	5	

ALIF, anterior lumbar interbody fusion; BMI, body mass index; N/A, not applicable; TDR, total disc replacement; TIAO, temporary iliac artery occlusion.

L4/5 level in addition to another level increased the rate of TIAO. Of the 61 patients who underwent multilevel ALIF including L4/5, TIAO occurred in 27 patients (44.3%). Among these patients, TIAO rates did not differ significantly between males and females (males vs. females: 14/30 [46.7%] vs. 13/31 [41.9%]; p=.85). Of the 5 patients who underwent multilevel TDR, TIAO occurred in only 1 patient.

Hybrid procedures were frequently associated with TIAO. Of the 118 patients who underwent a hybrid procedure, 77 developed TIAO, for an overall rate of 66.1%. Among these patients, TIAO rates were not significantly different between males and females (males vs. females: 38/62 [61.3%] vs. 40/56 [71.4%]; p=.66).

TIAO during revision procedures

Three patients underwent revision anterior spinal exposure at the same level for ALIF. None had TIAO.

Association with sex and body mass index

Regression analysis examining the correlation between sex and the occurrence of TIAO showed no correlation between sex and TIAO. The R value was only 0.46 indicating moderate positive linear correlation. The p-value of .018 associated with this test confirms its reliability.

There were 425 patients with complete BMI data. Their mean BMI was 26.7±3.9 kg/m^2 (range, 18–40kg/m^2). TIAO occurred in 34 of the 122 patients (28%) with a BMI=18–24 kg/m^2, 66 of the 226 patients (29%) with a BMI=25–30 kg/m^2, and 18 of the 77 patients (23%) with a BMI=31–40 kg/m^2. There was no significant difference in TIAO rates between BMI groups (p=.76).

Differences between prostheses

Overall, the rate of TIAO was significantly higher for TDR than for ALIF (p=.004). Of the 110 patients who underwent TDR, TIAO occurred in 47 patients (48%). By contrast, of the 377 patients who underwent ALIF, TIAO occurred in only 51 patients (14%). Subgroup analysis showed that at the L4/5 level, TDR was associated with a significantly higher rate of TIAO than ALIF (74.6% vs. 48.5%; p=.01).

ALIF at L4/5 versus L5/S1

In patients who underwent ALIF, the rate of TIAO was significantly higher during surgery at L4/5 than during surgery at L5/S1 (p=.001). Of the 33 patients who underwent ALIF at the L4/5 level, TIAO occurred in 16 patients (49%). By contrast, of the 281 patients who underwent ALIF at L5/S1, TIAO occurred in 8 patients (3%).

TDR at L4/5 versus L5/S1

In patients who underwent TDR, the rate of TIAO was significantly higher during surgery at L4/5 than during surgery at L5/S1 (p=.001). Of the 59 patients who underwent TDR at L4/5, TIAO occurred in 44 patients (75%). By contrast, of the 44 patients who underwent TDR at L5/S1, TIAO occurred in 2 patients (5%).

Sidedness of TIAO

TIAO occurred in the right common iliac artery in 5 patients. In 2 of these patients, bilateral common iliac artery occlusion occurred during L4/5 exposure. In the other 3 patients, isolated right common iliac artery occlusion occurred during L5/S1 exposure.

Deep vein thrombosis and iliac artery thromboembolic complications

Only one of the 605 patients (0.17%) developed a symptomatic iliofemoral DVT in the postoperative period. This 34-year-old female had pre-existing obesity and severe mobility-limiting rheumatoid arthritis. She received prophylactic enoxaparin postoperatively. There were no episodes of thrombotic iliac artery occlusion or embolic complications in the postoperative period.

Discussion

The incidence of thromboembolic complications associated with anterior lumbar exposure is low but well recognized, with rates of 0.45% to 0.9% [4,9,10]. We report for the first time the incidence of intraoperative TIAO secondary to retractive forces. Our data are highly relevant, as TIAO can be the precursor of thrombotic occlusion and lower extremity ischemia in the postoperative period. In the worst-case scenario, the consequences of the occlusion can be devastating. While some compression of the vessel by the retractors is to be expected, the substantial incidence of TIAO illustrates the significant forces applied to the arteries,

resulting in occlusion of the iliac artery during exposure. On detection of TIAO, an attempt is made to reduce the retractive forces by repositioning the retractors. The area over which the forces are applied is also increased with further retractor blades or vessel retraction pins to reduce arterial kinking. Despite these retractor modifications, TIAO may still occur. Our preoperative screening and exclusion of patients with major arterial pathology may explain the absence of postoperative arterial blockage or embolic complications despite the high rates of TIAO. These results quantify the frequency of arterial compression to occlusion during anterior exposure of the L4/5 levels. This illustrates the importance of screening with duplex ultrasound and/or CTA for arterial pathology preoperatively to avoid potentially catastrophic complications. In our series, the overall incidence of TIAO was 29%, but in some cohorts, it was over 80%.

We report here the largest series to date demonstrating the use of bilateral digital intraoperative pulse oximetry monitoring to detect iliac arterial occlusion during anterior lumbar exposure. Use of pulse oximetry monitoring on the left second toe was previously described in a 61-year-old male undergoing ALIF at levels L3/4 and L4/5 [11]. In our experience, pulse oximetry is ideally performed using the second toe, rather than the great toe. The saturation probes were designed for use on fingers, and in some patients, the great toe is too large in diameter resulting in poor or unreliable waveform recordings. The second toe is closer to the intended digital dimension.

Occlusion of a large proximal feeding artery (such as the iliac artery) leads to loss of the pulse waveform, although collateral supply can continue to provide some blood flow in a minimally pulsatile manner. The waveform component from the saturation meter (photoplethysmogram) is a sensitive noninvasive monitor of blood flow pulsatility. The loss of the saturation meter waveform, combined with loss of a previously palpable pulse, indicates that the artery is clinically occluded.

Right iliac artery occlusion during anterior spinal exposure has been rarely reported [9]. However, in 5 of our patients, TIAO occurred in the right iliac artery, either in isolation or in combination with TIAO of the left iliac artery. Bilateral occlusion was noted in 2 patients during exposure of the L4/5 level, most likely secondary to compression of the distal aorta. In the other cases, isolated right-sided occlusion occurred during L5/S1 exposure. As the aorta generally lies to the left of the midline, the right common iliac artery is more likely to cross the disc space and require more retraction than the left common iliac artery. We advocate using bilateral second-toe pulse oximetry monitoring for the majority of patients undergoing anterior lumbar spinal surgery.

In our series, the duration of TIAO was usually less than 30 minutes (range 25–50 minutes). However, there were procedures where disc exposure was difficult and the duration of occlusion was longer. In the case report by Konig et al, the duration of iliac artery occlusion was 55 minutes, resulting in iliac artery thrombosis with significant lower limb ischemia requiring urgent intervention [11]. We suggest that use of anticoagulation during the period of TIAO may have prevented this thrombotic complication. Heparin does not relieve the arterial obstruction but instead is administered to reduce the risks associated with occlusion. Heparin has potential complications such as retroperitoneal or epidural hematoma. However, the duration of anticoagulation is brief, and heparin is reversed as soon as retraction is released and the pulse waveform and palpable pulse return. It has been previously demonstrated that intraoperative heparinization can be used safely without adverse effects [6]. The use of pulse oximetry monitoring can guide judicious intraoperative heparinization.

TIAO occurred most frequently during surgery at the L4/5 level and was more common when a TDR prosthesis was used. The higher rate of TIAO with TDR than with ALIF was likely because of the need for more stringent symmetrical exposure at the vertebral midline for TDR, resulting in more vascular retraction. The incidence of TIAO with isolated L5/S1 anterior procedures was low, suggesting that perfusion monitoring may not be required for these procedures.

Sex was not significantly associated with TIAO on regression analysis. Females had a 10% higher incidence of TIAO than males, but the difference between sexes was not statistically significant. Major blood vessels are smaller in women than in men of the same race and age [3]. We postulate that these smaller vessels may be more vulnerable to compressive occlusion.

We also found that a higher BMI was not associated with an increased incidence of TIAO. This likely reflects our operative retraction technique, in which vessel retraction pins help hold the iliac vessels aside, independent of the table-mounted retractor. This divorces the retraction of the vessels from the force required to retract the abdominal viscera.

Although TIAO is often unavoidable during anterior exposure, careful patient selection to exclude patients with major arterial pathology and the judicious use of monitoring and brief intraoperative heparinization can minimize postoperative arterial complications and blockages.

The reported venous thromboembolism rate associated with spinal surgery is 1.1% [12]. We noted only 1 DVT in our series of patients. The addition of intraoperative heparinization may have contributed to our low incidence of venous thromboembolism (0.2%).

This study had several strengths, including our use of a prospectively collected database of consecutive patients. In addition, all procedures were performed by a single, experienced attending vascular surgeon and 5 attending spinal neurosurgeons, who utilized similar techniques and prostheses. Another strength was the use of a multimodality technique (pulse oximeter waveform combined with manual pulse palpation) to detect and confirm iliac artery occlusion. It is the first to accurately document the incidence of TIAO.

Our study also has some limitations. BMI data were available for only 425 of our 605 patients. Furthermore, the number of patients who underwent surgery at L3/4 or revision surgery was too small to adequately analyze. In multilevel procedures, we did not record the level of exposure resulting in TIAO. In future data collection, we plan to document whether occlusion occurs at each level.

Conclusion

TIAO was common during anterior lumbar spinal exposure, with an overall incidence of 29%. Exposure at the L4/5 level, particularly for TDR, had a significantly higher incidence of TIAO. Conversely, the incidence of TIAO was low with isolated L5/S1 level procedures. BMI and sex were not significantly associated with the occurrence of TIAO. These results quantify for the first time the high frequency of significant arterial compression during anterior exposure of the L4/5 level. Given the high incidence of TIAO, preoperative screening and exclusion of patients with major arterial pathology is crucial to avoid arterial blockage or embolic complications when exposing L4/5. Consideration should be given for monitoring limb perfusion during anterior lumbar spinal surgery, combined with targeted intraoperative heparization.

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Declarations of competing interests

The authors report no conflicts of interest for this study.

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