Rating the incidence of iatrogenic vascular injuries in thoracic and lumbar spine surgery as regards the approach: A PRISMA-based literature review

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Received: 26 April 2021 / Revised: 2 August 2021 / Accepted: 6 August 2021 / Published online: 19 August 2021 © The Author(s) 2021

Abstract

Purpose To assess the rate, timing of diagnosis, and repairing strategies of vascular injuries in thoracic and lumbar spine surgery as their relationship to the approach.

Methods PubMed, Medline, and Embase databases were utilized for a comprehensive literature search based on keywords and mesh terms to find articles reporting iatrogenic vascular injury during thoracic and lumbar spine surgery. English articles published in the last ten years were selected. The search was refined based on best match and relevance.

Results Fifty-six articles were eligible, for a cumulative volume of 261 lesions. Vascular injuries occurred in 82% of instrumented procedures and in 59% during anterior approaches. The common iliac vein (CIV) was the most involved vessel, injured in 49% of anterior lumbar approaches. Common iliac artery, CIV, and aorta were affected in 40%, 28%, and 28% of posterior approaches, respectively. Segmental arteries were injured in 68% of lateral approaches. Direct vessel laceration occurred in 81% of cases and recognized intraoperatively in 39% of cases.

Conclusions Incidence of iatrogenic vascular injuries during thoracic and lumbar spine surgery is low but associated with an overall mortality rate up to 65%, of which less than 1% for anterior approaches and more than 50% for posterior ones. Anterior approaches for instrumented procedures are at risk of direct avulsion of CIV. Posterior instrumented fusions are at risk for injuries of iliac vessels and aorta. Lateral routes are frequently associated with lesions of segmental vessels. Suture repair and endovascular techniques are useful in the management of these severe complications.

Keywords Aorta · Common iliac vein · Iatrogenic vascular injury · Inferior vena cava · Instrumented spine surgery · Spine surgery · Vascular injuries

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Introduction

Vascular injuries are rare but potentially life-threatening complications in thoracic and lumbar spinal surgery, having a reported incidence of 0.01% to 1%, and variable overall mortality that ranges between 15 and 65% [1–3]. The widening of the spectrum of the surgical corridors for the treatment of spinal diseases, frequently involving the dissection and mobilization of the major splanchnic vessels, has increased the risk of vascular injuries [4–7]. The occurrence of vascular lesions is related to the proximity of the thoracic and lumbar column to the retroperitoneal vascular structures, separated from the latter uniquely by the anterior longitudinal ligament [8, 9].

Clinical presentation is not always easily recognized, especially when the injury is related to a posterior approach. Several factors as the type of approach, vessel’s caliper, and mechanism of injury complicate the patient’s presentation and recognition of the injury. Direct damages, as arterial or venous laceration, generally lead to an acute retroperitoneal hemorrhage with abdominal distention, hypotension, and hematocrit drop [10, 11]. Conversely, delayed injuries can occur days, weeks, or even months following the procedure. They are characterized by a widening of the arterial pressure and tachycardia, which are possibly related formation of thrombi, pseudoaneurysms, or arteriovenous fistulas [12–16]. One difficulty to recognize the cause of delayed vascular injury relates to progressive damage to the vessel wall by prominent hardware [17–21].

A prompt diagnosis, adequate intraoperative management, and early repair are paramount to prevent devastating sequelae.

Nevertheless, literature about the incidence, recognition, and treatment of vascular injuries during thoracic and lumbar spine approaches is still limited, which contributes to a potential underestimation of the overall complication rate of this type of surgery.

The present study consists of a literature review on vascular complications of thoracolumbar spine surgery aimed to infer whether or not potential links do exist between the type of surgical approach, mechanism of injury, and type of injured vessel. Repair strategies and overall outcomes are also discussed.

Materials and methods

An online literature search was conducted on PubMed/MEDLINE and Embase search engines with combinations of Medical Subject Heading (MeSH) (PubMed) terms and text words. A Population, Intervention, Comparison, Outcome (PICO) search strategy was employed. The MeSH terms “thoracic spinal surgery” [MeSH], “lumbar spinal surgery” [MeSH], “anterior lumbar interbody fusion” [MeSH], “posterior lumbar interbody fusion” [MeSH], “lateral lumbar interbody fusion” [MeSH], “lumbar disc surgery” [MeSH] were combined with “vascular injury” [text word], “iatrogenic vascular injury” [text word], “vessel laceration” [text word], “thrombosis” [text word], “arteriovenous fistula” [text word], “pseudoaneurysm” [text word].

Clinical trials, reviews, cohort studies, and case reports in English or translated to English language and published in the last 10 years were selected. The relevance of each article about the primary endpoint of the study was established by three different independent researchers based on the match with the search terms. Apart from the match, relevance, and years, no further restriction criteria were applied. Overall data about the vascular injuries were extracted, and a descriptive analysis was performed.

Results

Literature volume

The literature search initially returned a total of 134 articles. After the removal of duplicates, 74 articles were assessed for eligibility. The application of the exclusion criteria led to the selection of 56 relevant articles for quantitative and qualitative analysis. Non-English articles excluded from the review amounted to 12. The overall level of evidence of the literature volume according to Strength of Recommendation Taxonomy (SORT) [22] has been low and consisting of 38 case reports (68%) and 18 retrospective case series (32%).

Studies concerning the anterior, posterior lateral approaches to thoracic and lumbar spinal pathologies were 38, 11, and 7, respectively. Figure 1 reports the PRISMA flowchart of the study (Fig. 1).

Demographic and clinical data

A total of 261 patients from 56 studies were included. Patients’ average age in the anterior, posterior, and lateral groups was 52.6 ± 11, 48 ± 15, and 57.5 ± 12 years old, respectively. The fifth decade was the more affected.

Tables 1, 2, and 3 summarize the main demographic and clinical data of the anterior, posterior, and lateral groups, respectively (Tables 1, 2, and 3).
Frequency of primary diseases

Spondylolisthesis was the indication for surgery in 87 cases (34%), followed by degenerative disc disease (24%), disc herniation (16%), scoliosis (11%), and fractures (6%). Less common diseases were osteomyelitis (4%), pseudarthrosis (3%), and spinal stenosis (2%) (Fig. 2).

Type of procedures

In 208 cases (82%), an instrumented thoracic or lumbar spinal surgery was performed. In the remaining cases, a discectomy, corpectomy, or osteophytectomy were carried out.

Operative levels

L4-L5 was the most affected level as it was involved 220 cases (12%), followed by L5-S1 (10%), L3-L4 (9%), L2-L3 (8%), and L1-L2 (7%), in this order of frequency. About the thoracic spine, no prevalence between the affected levels was observed (Fig. 3).

Surgical approaches

One hundred and fifty-four patients (59%) underwent an anterior approach, of which 86 consisted of an anterior lumbar interbody fusion (ALIF). A posterior approach was performed in 85 (33%) patients, and a posterior...
| #   | Author, year  | Study type | Average Pts. | Primary disease (N°)                         | Procedure | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury (N°) | Time to diagnosis/technique | Treatment (N°) | Outcome (N°) |
|-----|---------------|------------|--------------|------------------------------------------------|-----------|---------------------|----------|----------------|---------------------|----------------------|-----------------------------|----------------|-------------|
| 1   | Garg et al., 2010 | RCS        | 53           | DDD Spondylolisthesis | Discectomy Arthrodesis | L4-L5 (2) L4-L5, L5-S1 (7) L5-S1 (4) | ALIF     | 13            | Branch of Left CIV (8) Left CIV (3) Right CIV (1) Left IIA (1) FA (1) Hypogastric Vein (1) | Laceration (12) Thrombosis (1) Intraoperative | Direct suture (12) Thrombectomy and Stent placement (1) | Discharged without symptoms |
| 2   | Hans et al., 2011 | RCS        | NA           | Spondylolisthesis | Arthrodesis Lumbar | ALIF     | 5              | CIA (4)              | Thrombosis (4) Laceration (1) | NA                     | NA                          | Stent (3) Thrombectomy (2) | Discharged without symptoms |
| 3   | Zahradnik et al., 2012 | RCS       | 50           | DDD Spondylolisthesis Scoliosis Osteomyelitis Pseudoarthrosis | Arthrodesis Thoracic Lumbar | Anterior 40 | Left CIV (21) UN small arteries (7) IVC (4) LV (2) LA (2) Left IIA (1) Left IV (1) Aorta (1) Left CIA (1) | NA | NA | Direct Suture (29) Clips (8) Open Ligation and Suture (7) Stent (2) Graft (1) | NA |
| 4   | Quraishi et al., 2012 | RCS       | 43           | DH Spondylolisthesis Scoliosis Osteomyelitis Pseudoarthrosis | Arthrodesis | L3-L4 L4-L5 L5-S1 | ALIF     | 19            | Veins (19) Arteries (5) | Laceration | NA | Direct Suture (17) Thrombectomy (2) | NA |
| 5   | Akinrinlola et al., 2013 | CR       | 32           | Thoracic Epidural Abscess | Corpectomy Arthrodesis | T6-T9 | Anterior 1 | Aorta | Laceration | Post-operative/CT | Graft | Discharged without symptoms |
| 6   | Ballard et al., 2014 | RCS       | 56           | Spondylolisthesis DDD Osteomyelitis | Arthrodesis Thoracic lumbar | ALIF | 13         | Arteries | Veins | Thrombosis Laceration | NA | NA |
| #  | Author, year | Study type | Average Pts. Age | Primary disease (N°) | Procedure | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury (N°) | Time to diagnosis/technique | Treatment | Outcome (N°) |
|----|--------------|------------|------------------|----------------------|------------|---------------------|----------|----------------|-------------------|------------------|-------------------------|-----------|-------------|
| 7  | Klezl et al., 2014 | RCS | NA | NA | Discectomy Corpectomy | Thoracic lumbar | Anterior | 14 | CIV (9) IVC (2) Arteries (2) EIV (1) | Laceration | Intraoperative | NA | NA |
| 8  | Fischer et al., 2014 | CR | 67 | Spondylolisthesis | Arthrodesis | L4-L5, L5-S1 | ALIF | 1 | Left CIA | Laceration | Post-operative 10 h/CTA | Thrombectomy | Discharged without symptoms |
| 9  | Mobbs et al., 2016 | RCS | NA | DDD | Scoliosis Revision surgery | Arthrodesis | Lumbar | ALIF | 15 | IVC (9) EIV (1) CIV (4) LV (1) | Laceration | Intraoperative | NA | NA |
| 10 | Mehren et al., 2016 | RCS | 63 | NA | Arthrodesis | L4-L5 | ALIF | 3 | Left CIV (1) Right CIV (1) Aorta (1) | Laceration | Intraoperative | Direct Suture Hemostatic agents | Discharged without symptoms |
| 11 | Momin et al., 2020 | RCS | 57 | Spondylolisthesis | Arthrodesis | L3-L4, L4-L5, L5-S1 | ALIF | 30 | CIV (27) CIA (1) IVC (1) Aorta (1) | Laceration | Intraoperative | NA | NA |

ALIF Anterior lumbar interbody fusion; CIA common iliac artery; CIV common iliac vein; CR case report; CT computed tomography; CTA computed tomography angiography; DDD degenerative disc disease; DH disc herniation; DSA digital subtraction angiography; EIV external iliac vein; FA femoral artery; IIA internal iliac artery; IV inferior vena cava; LA lumbar artery; LV lumbar vein; NA not available; Pts: patients; RCS retrospective case series study; UN: Unknown.
| #  | Author, year       | Study type | Average Pts. Age | Primary disease (N°)                        | Procedure                        | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury (N°) | Time of diagnosis/technique | Treatment                      | Outcome (N°) |
|----|-------------------|------------|-----------------|---------------------------------------------|-----------------------------------|----------------------|----------|----------------|-------------------|-------------------|-------------------------------|--------------------------------|-------------|
| 1  | Karaikovic et al., 2010 | CR         | 48              | DH                                          | Discectomy                        | L4-L5                | Posterior | 1              | LA                | Laceration         | Intraoperative/DSA             | Endovascular thrombectomy       | Discharged without symptoms |
| 2  | Hu et al., 2010    | CR         | 52              | Osteomyelitis                                | Arthrodesis                       | T2-T5                | Posterior | 1              | Aorta             | Impingement         | Postoperative 8-month/CT      | Stent-graft                     | Discharged without symptoms |
| 3  | Watanabe et al., 2010 | CR         | 57              | T12 Fracture                                | Arthrodesis                       | T10-L2               | Posterior | 1              | Aorta             | Impingement         | immediate Postoperative/CT    | Direct suture                  | Discharged without symptoms |
| 4  | Karwacki et al., 2010 | CR         | 25              | Disc herniation                             | Discectomy                        | L4-L5                | Posterior | 1              | Left CIA          | Laceration         | NA                            | Direct suture                  | Discharged without symptoms |
| 5  | Kim et al., 2010   | RCS        | 50              | Spinal Deformity                            | Osteophysectomy                   | L2-L3 (4)            | Posterior | PLIF           | Aorta (3)         | Laceration         | Intraoperative (1) Immediate Postoperative (5) Post-operative 1st day-5 month(6) DSA (4) | Open Ligation and Suture (7) Endovascular Embolization (2) Stent-Graft (1) | Died (3) |
| 6  | Yi et al., 2010    | CR         | 57              | DH                                          | Discectomy                        | L4-L5                | Posterior | 1              | Right EIA         | Laceration         | Intraoperative               | Direct Suture                  | Discharged without symptoms |
| 7  | Yip et al., 2011   | CR         | 70              | DH                                          | Discectomy                        | L4-L5                | Posterior | 1              | Aorta             | Laceration         | Intraoperative               | Direct Suture                  | Discharged without symptoms |
| 8  | Clarke et al., 2011 | CR         | 71              | T8 Burst Fracture                           | Arthrodesis                       | T6-T10               | Posterior | 1              | Thoracic Aorta    | Laceration         | Postoperative 6-month         | Stent                         | Discharged without symptoms |
| 9  | Bozok et al., 2012 | RCS        | 36              | DH                                          | Discectomy                        | L4-L5 (4) L5-S1 (2)  | Posterior | 7              | Left CIA (5)      | Laceration         | Intraoperative (3) Postoperative 1-3 h (4)VCTA, DSA | Direct Suture Graft End-to-end Anastomosis | Paraplegia (1) |
| 10 | Jin et al., 2012   | CR         | 72              | DH                                          | Discectomy                        | L4-L5                | Posterior | 1              | Left CIA          | Laceration         | Intraoperative               | Endovascular Stenting           | Discharged without symptoms |
| #  | Author, year       | Study type | Average Pts. | Primary disease (N°) | Procedure       | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury(N°) | Time of diagnosis/technique | Treatment | Outcome (N°) |
|----|--------------------|------------|--------------|----------------------|-----------------|----------------------|----------|----------------|---------------------|---------------------|--------------------------------|-----------|--------------|
| 11 | Olcay et al., 2013 | CR         | 50           | DH                   | Discectomy      | L4-L5 (1) L5-S1 (1) | Posterior | 1              | Left CIA            | Laceration          | Intraoperative                | Graft     | Discharged without symptoms |
| 12 | Park et al., 2013  | CR         | 48           | DH                   | Discectomy      | L4-L5             | Posterior | 1              | Right CIA (1) Right CIV (1) | Fistula            | Postoperative/CT, DSA                | Endovascular Graft | Discharged without symptoms |
| 13 | Keskin et al., 2013| CR         | 32           | DH                   | Discectomy      | Lumbar             | Posterior | 3              | Left CIA (3) Left CIV (1), Right CIV (1) | Laceration          | Postoperative 6-20 h/CTA | Suture (1) Graft (1) Ligation (1) | CID (1) |
| 14 | van Zitteren et al., 2013 | CR | 53           | DH                    | Discectomy      | L4-L5 (1) L5-S1 (1) | Posterior | 2              | Right CIA (1) Right IIV (1) | Laceration          | Intraoperative                | Stent (1) Endovascular Embolization (1) | Discharged without symptoms |
| 15 | Singh et al., 2013  | CR         | 39           | DH                   | Discectomy      | L4-L5             | Posterior | 1              | CIA, CIV            | Laceration          | Intraoperative                | Anastomosis CIV-Gonadal vessel | Edema of Lower Extremity |
| 16 | Yildiz et al., 2013 | CR         | 31           | DH                   | Discectomy      | L3-L4             | Posterior | 1              | Aorta               | Laceration          | Postoperative 10 h              | End-to-end anastomosis Suture | Discharged without symptoms |
| 17 | Postacchini et al., 2013 | CR | 52           | DDD                  | Arthrodesis     | L4-L5             | PLIF      | 1              | Left CIV (1) Right CIA (1) | Laceration          | Post-operative 4 h            | Suture | Died |
| 18 | Sugimoto et al., 2013 | CR | 73           | L2 Burst Fracture Spondylolisthesis | Arthrodesis       | T12-L2 (1) L4-L5 (1) | PLIF     | 2              | Right LA (1) Left LA (1) | Laceration          | 1–2 Postoperative week/CTA, DSA | Endovascular embolization | Discharged without symptoms |
| 19 | Chao et al., 2013   | CR         | 44           | DH                   | Discectomy      | L4-L5             | Posterior | 1              | Right CIA           | Pseudoaneurysm     | Postoperative 3 day            | Suture | Discharged without symptoms |
| 20 | Decker et al., 2014 | CR         | 33           | T2-T10 Fracture      | Arthrodesis     | T2-T10            | Posterior | 1              | Aorta               | Impingement           | Postoperative 13-month/CTA | NA | Discharged without symptoms |
| 21 | Parker et al., 2014 | RCS        | 56           | DDD Spondylolisthesis Tumor, Trauma | Arthrodesis      | Thoracic Lumbar | Posterior | 15             | Aorta (10) CIV (4) IIV (1) | Laceration          | NA                | NA | NA |
| #  | Author, year       | Study type | Average Pts. Age | Primary disease (N°) | Procedure | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury (N°) | Time of diagnosis/technique | Treatment (N°) | Outcome (N°) |
|----|--------------------|------------|------------------|----------------------|-----------|---------------------|----------|----------------|---------------------|---------------------|---------------------------|----------------|-------------|
| 22 | Tan et al., 2014   | CR         | 26               | Scoliosis            | Arthrodesis | T3-T4               | Posterior | 1              | Aorta               | Pseudoaneurysm       | Postoperative 10-year/CTA | Graft             | Discharged without symptoms |
| 23 | Wee et al., 2015   | CR         | 29               | Stenosis             | Laminec- tomy | L4-S1               | Posterior | 1              | Right CIA           | Pseudoaneurysm       | Postoperative 12 h Endovascular embolization | Suture            | Discharged without symptoms |
| 24 | Busardo et al., 2015 | CR         | 52               | DH                   | Disectomy   | L4-L5               | Posterior | 1              | Left CIA            | Laceration          | Postoperative 3 h     | Discharged without symptoms |
| 25 | Ariyoshi et al., 2015 | CR         | 74               | Scoliosis            | Deformity Correction | Lumbar | Posterior TLIF | 1              | Cage migrated in IVC | Laceration          | Postoperative Cage removal and vein ligation | Discharged without symptoms |
| 26 | Riedemann-Wistuba et al., 2016 | RCS       | 50               | DH                   | Spondylolisthesis Disectomy (3) | L4-L5 (4) L5-S1 (2) | Posterior (3) | 4              | Left LV (2) Right CIA (2) Right CIV (2) Left IIA (1) Left CIA (1) IVC (1) | Laceration (2) Fistula (2) Intraoperative (2)/ CTA (2) Postoperative 9–60 month/ DSA (1) | Direct Suture, Graft (3) Endovascular Embolization (1) | Postphlebitic syndrome (1) |
| 27 | Baser et al., 2016 | CR         | 20               | DH                   | Disectomy   | L4-L5               | Posterior | 1              | Right IIA           | Laceration          | Intraoperative Suture | Discharged without symptoms |
| 28 | Huttman et al., 2016 | CR         | 35               | DH                   | Disectomy   | L4-L5               | Posterior | 1              | Right CIV (1) Right CIA (1) | Pseudoaneurysm       | Intraoperative Endovascular Stenting | Discharged without symptoms |
| 29 | Mirza et al., 2016 | CR         | 52               | T6-T7 Compression Fracture Spondylolisthesis | Arthrodesis T5-T11 (1) T10-L5 (1) L4-S1 (1) | Posterior PLIF | 3              | Thoracic Aorta (2) Left CIV (1) Laceration (1) | Pseudoaneurysm (2) Laceration (1) Postoperative/ CTA | Postoperative/ CTA Stent | Discharged without symptoms |
| 30 | Gok et al., 2017   | RCS        | NA               | NA                   | NA         | Lumbar              | Posterior | 6              | CIA, CIV (6)        | Fistula (6)         | 1–12 Postoperative week/CTA, MRA | Stent (6)          | Discharged without symptoms |
| 31 | Álvarez et al., 2017 | CR         | 77               | Lumbar Stenosis     | Arthrodesis | L3-L4 (1), L4-L5 (1) | PLIF      | 1              | LA                  | Laceration          | Intraoperative/ DSA Thrombectomy | Discharged without symptoms |
| 32 | Ventura et al., 2017 | CR         | 38               | DH                   | Disectomy   | L5-S1               | Posterior | 1              | LA                  | Laceration          | Intraoperative None | Died |

Table 2 (continued)
| #  | Author, year | Study type | Average Pts. | Age | Primary disease (N°)       | Procedure        | Operative level (N°) | Approach | N° of injuries | Injured vessel (N°) | Type of injury (N°) | Time of diagnosis/technique | Treatment | Outcome (N°) |
|----|--------------|------------|--------------|-----|---------------------------|------------------|---------------------|----------|----------------|---------------------|------------------------|----------------------------|-----------|--------------|
| 33 | Kassé et al., 2018 | CR | 48 | | T7-T8 Burst Fracture | Arthrodesis | T5-T10 | PLIF | 1 | Aorta | Impingement | Postoperative/MRI | Screw removal | Discharged without symptoms |
| 34 | Kayaci et al., 2019 | CR | 50 | | Thoracicolumbar Fractures | Arthrodesis | T10-L1 (1) T11-L2 (1) T12-L4 (1) | Posterior | 3 | Aorta | Impingement | Postoperative/DSA | Endovascular Graft | Discharged without symptoms |
| 35 | Takashima et al., 2019 | CR | 19 | | | Discectomy | L4-L5 | Posterior | 1 | CIA | Laceration | Intraoperative | Graft | Discharged without symptoms |
| 36 | Sahinoglu et al., 2019 | CR | 50 | | | Discectomy | L4-L5 | Posterior | 1 | Left CIA | Laceration | Intraoperative/CT/CTA | Stent | Discharged without symptoms |
| 37 | Yalvac et al., RCS 2020 | RCS | 58 | | | Discectomy | L4-L5 | Posterior | 2 | Left CIA (1) Left CIV (1) | Laceration (1) Fistula (1) | Postoperative/CTA | Suture | Died (1) |
| 38 | Kwinta et al., 2020 | CR | 50 | | | Discectomy | L4-L5 | Posterior | 2 | CIA (1) CIV (1) | Laceration (1) Fistula (1) | Immediate Postoperative/CTA | Stent (1) Femorofemoral bypass (1) | Discharged without symptoms |

CIA: Common iliac artery; CID: disseminated intravascular coagulation; CIV: common iliac vein; CR: case report; CT: computed tomography; DDD: degenerative disc disease; DH: disc herniation; DSA: digital subtraction angiography; EIA: external iliac artery; IIA: internal iliac artery; IV: internal iliac vein; IVC: inferior vena cava; LA: lumbar artery; LV: lumbar vein; MRA: magnetic resonance angiography; NA: not available; PLIF: posterior lumbar interbody fusion; Pts: patients; RCS: retrospective case series study; TLIF: transforaminal lumbar interbody fusion
## Table 3  Review of vascular injuries in lateral approaches for thoracic and lumbar spinal pathology

| #  | Author, year      | Study type | Average Pts. | Age | Primary disease (N°) | Procedure | Operative level (N°) | Approach | N° Injury (N°) | Injured vessel | Type of injury (N°) | Time of diagnosis/technique | Treatment (N°) | Outcome (N°) |
|----|-------------------|------------|--------------|-----|----------------------|------------|----------------------|----------|----------------|---------------|-------------------|-----------------------------|---------------|--------------|
| 1  | Santillan et al., 2010 | CR         | 55           | NA  | Arthrodesis          | L2-L3      | LLIF                 | 1        | LA             | CIA           | Pseudoaneurysm     | Postoperative/DSA          | Embolization   | Discharged without symptoms |
| 2  | Sandhu et al., 2013 | CR         | 41           | T4-T5 Fracture | T4-T6      | Arthrodesis          | LLIF                 | 1        | Thoracic Aorta | Laceration | Postoperative 2 year/CT | Graft            | Discharged without symptoms |
| 3  | Kueper et al., 2015 | RCS        | 61           | NA  | Arthrodesis          | L1-L5      | LLIF                 | 5        | Segmental artery (4) | Laceration | NA               | NA               | Discharged without symptoms |
| 4  | Aichmair et al., 2015 | CR         | 50           | NA  | Scoliosis Stenosis   | Arthrodesis | LLIF                 | 1        | Lumbar Aorta  | Laceration | Intraoperative | Direct suture | Discharged without symptoms |
| 5  | Abe et al., 2016 | RCS        | NA           | 76  | Spondylolisthesis    | Thoracic Lumbar | OLIF | 6 | Segmental artery | Laceration | Intraoperative | NA | NA |
| 6  | Ntourantonis et al., 2018 | CR         | 76           | L1 Osteoporotic Fracture | T11-L3 | Corpectomy Arthrodesis | LLIF | 1 | Left L3 Segmental artery | Laceration | 2 Postoperative day/CT | None | Died |
| 7  | Zeng et al., 2018 | RCS        | 62           | NA  | DDD Spondylolisthesis | Spinal Deformity | OLIF | 7 | CIA (1) CIA (1) Ovarian vein (1) | Laceration | CTA MRI | Direct suture (6) Pressing hemostasis | NA |

CIA: common iliac artery; CIV: common iliac vein; CR: case report; CT: computed tomography; CTA: computed tomography angiography; DDD: degenerative disc disease; DH: disc herniation; DSA: digital subtraction angiography; LLIF: lateral interbody fusion; MRI: magnetic resonance imaging; OLIF: oblique lumbar interbody fusion; NA: not available; Pts: patients; RCS: retrospective case series study
lumbar interbody fusion (PLIF) in 20 cases. Among the lateral approaches, oblique lumbar interbody fusion (OLIF) and lateral lumbar interbody fusion (LLIF) were performed in 13 and 9 cases, respectively (Fig. 4).

Injured vessels

Two hundred and sixty-one vascular injuries were reported, with a prevalence of venous ones (56%). The most involved vessels in the order of frequency were as follows: common iliac vein (CIV) (38%), common iliac artery (CIA) (16%), aorta (12%), lumbar artery (LA) (8%), inferior vena cava (IVC) (7%), and segmental arteries (SA) (6%). During anterior approaches, the most affected vessels were the CIV (49%), IVC (10%), CIA (4%), and aorta (3%). Conversely, CIA, CIV, aorta, and LA were involved in posterior approaches. The lateral approach was mainly associated with injury of the SA (54%) (Fig. 5).

Mechanism of injury

The most frequent type of injury was by far a direct laceration of the vessel (81%), whereas thrombosis (8%), fistula (5%), pseudoaneurysm (3%), and impingement (3%) had a lower incidence.

Time to diagnosis

A direct inspective intraoperative diagnosis was achieved in 102 cases (39%). In the remaining 55 patients where the data were reported, computed tomography angiography (CTA), digital subtraction angiography (DSA), and computed tomography (CT) led to the diagnosis in 62%, 29%, and 9% of cases, respectively, for both arterial and venous injuries.

Repairing strategies

Direct repair with sutures of the artery or vein was possible in 113 patients. Endovascular techniques allowed to
treat the vascular damage in 56 cases; within these, stent-graft, thrombectomy, and embolization were utilized in 21%, 4%, and 4% of cases, respectively. In surgical repairing techniques, clipping, anastomosis, and bypass were performed in 4%, 3%, and 1% of patients, respectively. The release of topical hemostatic agents was sufficient in only 4 cases (2%).

**Overall outcome, morbidity, and mortality rate**

Eighty-four patients (32%) were discharged without symptoms. Only for posterior approaches, one case of paraplegia, one of disseminated intravascular coagulation, one of edema of the lower extremity, and one of postphlebitic syndrome were recorded, with a morbidity rate of 1%. The overall mortality calculated on the pooled cohort was 2%, of which the 90% (7 patients) for the posterior approach.

**Discussion**

The present literature review is aimed at an overview of the rate of iatrogenic approach-related vascular complications in thoracic and lumbar spine surgery. Questions about a putative correlation between the type of surgical corridor, and rate and type of injury have been addressed, in the obvious assumption that prompt recognition of these harmful complications is paramount for appropriate and effective management.

**Anterior approaches**

Anterior approaches to the thoracic and lumbar spine provide better exposure of the ventral surface of vertebral discs, with the main advantage of avoiding manipulation of the paravertebral muscles and ligaments, and a consequent lesser postoperative pain and risk of mechanical instability.
as well as direct access to the disc and release of the anterior longitudinal ligament (ALL), placement of cages with a wider footprint and possibility of achieving better restoration of lumbar lordosis [23]. During anterior approaches, the thoracoabdominal aorta, vena cava, iliac vein, and segmental vessels are mobilized and retracted to reach the anterior surface of the spine, for levels above L5-S1. Accordingly, the incidence of damages of the abdominal vessels unavoidably increased, resulting in a higher relative risk of vascular injuries related to the anterior approaches [4, 24].

Concerning the transthoracic anterior approaches, Ballard et al. reviewed 617 anterior thoracic and lumbar spine exposures, reporting 13 (2%) vascular injuries [25]. Intercostal arteries and thoracic aorta were the most affected in their series.

Clip ligation of the intercostal arteries, lung deflation, mobilization of the diaphragm, and removal of the inferior ribs were the strategies suggested facilitating disc exposure and at the same time reducing the risk of thoracic vessels’ lesions [25].

About the lumbar and lumbosacral spine, Garg et al. estimated the incidence of vascular injuries in 212 patients that underwent ALIF [26], of which 6.1% of cases were intraoperative vascular damages and a direct laceration of left CIV in 61.5% of cases. Notably, L5-S1 was the level affected in 70% of these procedures, where usually there is minimal mobilization of the vasculature, given that the procedure is carried out below the bifurcation and in between the iliac vessels.

In 2012, Zahradnik et al. published a retrospective review on 269 thoracic and lumbar anterior surgical procedures where they found a rate of vascular injuries of 13.8%, along with the involvement of the CIV in 52.5% of cases [6]. On a further series of 1262 left-sided anterior thoracic and lumbar surgeries by Klezl and colleagues, the overall rate of vascular injuries was 1.1%, with the CIV interested in 65%
of patients [27]. Recently, in 2020, Momin et al. reported 30 vascular lesions during 660 ALIFs, 27 of which were once again intraoperative lacerations of the CIV [28].

By the literature, our review highlighted a higher incidence of vascular lesions during anterior approaches (59%) in comparison with the posterior (33%) and lateral ones (8%). Not surprisingly, this rate was even higher for instrumented procedures because the positioning of pointed pedicle screws could easily injure vascular structures. At L5-S1, CIV was the most affected vessel (49%). Conversely, IVC and iliolumbar veins were mostly injured during procedures targeting the L4-L5 and L3-L4 disc space, respectively. The most frequent mechanism of damage during anterior approaches is the direct avulsion of a vein encountered along the surgical route. The rationale explanation lies in the greater fragility of the venous wall, consisting of a minor elastic component, making them more vulnerable than the arteries. On the other hand, despite an increased risk of vascular injury, anterior access allows for an easier exposure of the damaged vessel, direct control of the bleeding, and repairing of the vessel wall, which is achieved by means of a direct, often straightforward, suture in most cases. Vein repairing strategy usually entails the employment of monofilament nonabsorbable stiches.

Concerning the arterial counterpart, the CIA was found to be the most damaged during anterior procedures. CIA avulsion is a fearsome complication of the anterior lumbar retroperitoneal approach that can lead to claudication, ischemia, and lifetime paraplegia. In 2011, Hans et al. reported 4 cases of CIA injuries, consisting of thrombosis in 3 cases and laceration in one case [29, 30]. Retraction and mobilization of the great arteries are thought to potentially cause a small dissection of the intimal wall, ultimately resulting in thrombosis and vessel occlusion. In anterior lumbar procedures, bilateral pulse oximetry has been suggested as a useful tool to detect intraoperatorively the arterial vessel damage at an early stage, allowing its immediate treatment [31]. Arterial repairing techniques generally encompass an open arteriotomy, angioplasty, or endovascular stent placement [32–35].

**Posterior approaches**

Posterior approaches are related to a significantly lower risk of vascular complications, negligible in the present review (0.05%–0.08%). The rationale lies in the anatomy of the surgical route, which does not require exposure and mobilization of the retroperitoneal vessels [36, 37].

Some case reports have discussed injuries to the thoracic aorta during posterior instrumented surgery, almost all sustained by impingement or avulsion of the artery leading to a delayed hemothorax [38–40]. Parker et al. retrospectively examined 964 patients who underwent thoracic and lumbar screw fixation procedures, finding 10 thoracic pedicle screws that encroached the thoracic aorta. Four lumbar screws damaged the CIV and 1 the IIV [20]. Riedemann-Wistuba et al. reported 4 cases of vascular injuries that occurred during PLIF, involving the CIA and CIV [41]. Kwinta et al. recently reported 2 further cases of iliac vessel injuries during PLIF. The first was a direct avulsion of the CIA, which was treated by means of stent

### Incidence of Vascular Injuries

| ANTERIOR APPROACHES | POSTERIOR APPROACHES | LATERAL APPROACHES |
|---------------------|----------------------|-------------------|
| Inferior Vena Cava  | Aorta                | Segmental Arteries |
| 10%                 | 23%                  | 54%               |
| Common Iliac Vein   | Common Iliac Artery  |                   |
| 49%                 | 33%                  |                   |
| Aorta               | Common Iliac Artery  |                   |
| 23%                 | 5%                   |                   |
| Lumbar Artery       |                       |                   |
| 5%                  |                       |                   |

Fig. 5 Incidence of vascular injuries in anterior, posterior, and lateral approaches
placement, whereas the second consisted of a laceration of iliac vessels, leading to the formation of an arteriovenous fistula. The latter was repaired by a temporary femorofemoral bypass, followed by stent implantation in the right CIA [42]. Concerning the non-instrumented lumbar procedures, the risk of vascular injuries during lumbar disc surgery is low but should not be underestimated as this is a potentially catastrophic complication, to the point to be defined by some authors as the nightmare of this procedure [3, 43–51].

On a small series, Bozok et al. documented 6 CIA injuries (5 left, 1 right) and 2 CIV (1 left, 1 right) occurred in 7 lumbar discectomies [52].

Our study demonstrated that 33% of vascular injuries occurred during posterior approaches, of which only 24% happened during instrumented surgery.

In posterior instrumented surgery, the vascular injuries are theoretically attributable to the incorrect placement of the screw tip in the proximity to the vessel wall. Conversely, a possible explanation for the paradoxically even higher rate of vascular injuries in posterior non-instrumented surgery lies in the different aim of most of the posterior non-instrumented approaches where, for example in lumbar discectomy, it is required to manipulate the disc with a consequent higher probability that curettes or rongeurs may accidentally be deepened beyond the anterior longitudinal ligament injuring the retroperitoneal vessels. This aspect makes complex also repairs of these injuries that are burdened by significant mortality as reported, for example, in lumbar discectomy [36, 49, 53].

CIA, CIV, and aorta were involved in 40%, 28%, and 28% of cases, respectively. Laceration of CIA causes a wide retroperitoneal hemorrhage, which is not always identifiable intraoperatively, and that has to be always suspected in the light of a sudden intraoperative or postoperative hypotension.

Contrary to the anterior approaches, the main difficulties in vascular repairing of a retroperitoneal major vessel during the posterior routes lie in the urgent need for turning the patient supine to perform an anterior, retro- or transperitoneal approach.

Secondary injuries, caused by the impingement of hardware or cages to the vessel wall, are generally managed by a redo surgery or implant removal.

The formation of pseudoaneurysms and arteriovenous fistulas has also been described as delayed consequences of a chronic mechanical insult to the vessel wall. The presence of a pseudoaneurysm should be suspected in the presence of a pulsating abdominal mass with distension and pain, whereas arteriovenous fistulas may cause cardiopulmonary disturbances, tachycardia, intermittent claudication, and lower limbs edema [36, 44, 52, 54].

Endovascular techniques, such as stent-graft placement, embolization, and thrombectomy, have proven to be useful in the re-establishment of blood flow [55, 56].

Lateral approaches

In 2006, Ozgur et al. firstly described the lateral approach to the lumbar spine, namely the LLIF or XLIF [57]. It provides access to the lumbar vertebral discs through a retroperitoneal transpsoas route. Later, the so-called anterior to psoas approach, also known as OLIF, was introduced to avoid the mechanical consequences of the psoas muscles imbalance [58, 59].

Sandhu et al., in 2013, reported 2 cases of screw penetration of the thoracic aorta during lateral transthoracic approaches, both treated by open repair [60]. In 2015, Kueper et al. estimated at 0.056% the incidence of vascular injuries in 900 patients who underwent LLIF [61]. In their series, 4 patients incurred segmental vessel damage and 1 sustained a direct laceration of the abdominal aorta. All injuries were repaired by direct ligature or suture, and no patients suffered long-term sequelae [61].

In 2016, Abe et al. conducted a retrospective review of 155 patients who underwent an OLIF procedure, where 6 segmental vessel injuries (3% of the overall series) were reported [62].

Zeng et al., in 2018, analyzed 235 OLIFs, reporting 7 cases of vascular damages of segmental arteries in 4 cases, iliac vessels in 2 cases, and ovarian vein in the remaining case [63].

The present review overall found 22 vascular injuries (8%) during lateral approaches. The most frequent mechanism of damage was the direct focal laceration of the segmental vessels (54% of cases), because of the need for mobilization and ligation during LLIF and OLIF. Segmental vessel avulsion can be promptly controlled by direct pressure and topical hemostatic agents.

Management tips

Regardless of the surgical corridor, some important aspects emerged from this study, which should be intended as tips to decrease the risk of iatrogenic vascular injuries during spine surgery, as well as to adequately manage them during or after surgery.

The vascular anatomy should be understood preoperatively to identify potential variants, especially when planning anterior or lateral thoracic and lumbar spine approaches.

Preoperative planning is crucial also for cervical spine surgery, where the detection of the carotid and vertebral artery courses and eventual anatomical variants is fundamental.
Iatrogenic carotid artery injuries during anterior cervical spine surgeries are rare and not extensively reported in the literature. There is neither evidence that the prolonged carotid artery sheath traction during anterior cervical approaches results in the reduction of carotid blood flow and cerebrovascular accidents [64–66]. Vertebral artery damages due to anterior cervical spine procedures are infrequent, with an incidence of 0.1–0.5% [55, 67, 68].

As regards posterior cervical approaches, especially for upper cervical spine surgeries, the course of both vertebral arteries must be investigated preoperatively. Its laceration is a potentially fatal complication with an incidence rate ranging between 0.07 and 8% [69, 70].

Diagnostic tools to be considered are CT or MRI angiography, and in selected cases, additional vascular studies can be performed as needed [71–73]. In addition, the depth of the vertebral disc to the retroperitoneum should be measured on axial imaging studies for a safer placement of the surgical instruments [46, 54, 74].

Surgical timeout must include the presence of blood products and immediate needs tools such as large bore suckers, topical hemostats, clips, ligature, and vascular sutures [30, 75]. Adequate intraoperative hemodynamic parameters monitoring must be ensured by the anesthesiology team, with immediate detection of changes in pressure, hematocrit, and arterial pulse [4, 37].

After surgery, in case of suspected vascular injury, it is mandatory to perform CTA or, if the patient is hemodynamically stable, and angiography. Furthermore, dye-based methods of intraoperative visualization of the blood flow are useful to early detect the source of bleeding and also to perform a timely treatment by means of techniques coming from neurovascular surgery and described elsewhere by our group [76, 77].

Limitations

This literature review has some limitations. They are the heterogeneity as well as retrospective nature of the studies included of which more than half results from case reports (68%) and involved a relatively limited number of patients. These aspects inevitably rise the likelihood of biases. A further limit to be taken into account lies in the overall experience of the surgical teams, which affects both the rate of vascular injury and the promptness and efficacy of the repairing techniques.

Conclusion

The literature reported an overall incidence of iatrogenic vascular injuries during thoracic and lumbar spine surgery which is not negligible. The mortality rate of these complications varies widely among the series included in the review, ranging between 15 and 65%, also considering the prevalence of case reports (68%) and the low level of evidence.

Anterior approaches to the thoracic and lumbar spine are burdened by a higher risk of direct venous avulsion, especially CIV and IVC. Posterior instrumented fusion has been associated with a greater risk of damage to iliac vessels and aorta. The more recent lateral corridors have to face the handling of the segmental vessels. Repairing strategies involve direct suture and endovascular techniques, both having a primary role in decreasing the overall mortality of these rare but severe complications.

Funding
Open access funding provided by Università degli Studi di Pavia within the CRUI-CARE Agreement.

Declarations

Conflict of interest
The authors declare that there is no conflict of interest.

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