Original Article

Establishment of the prone transpsoas fusion surgery in Australia—a survey and analysis of major complications in early adopters

Vijidha Shree Rajkumar[1,2]^, Brian Owler[2,3,4], Bryden Dawes[5], Idrees Sher[6,7], Yi Yuen Wang[5,8]

[1]O Spine, Sydney, NSW, Australia; [2]Department of Neurosurgery, Sydney Adventist Hospital, Sydney, NSW, Australia; [3]Sydney Clinical School, Australian National University, Sydney, NSW, Australia; [4]Department of Neurosurgery, Norwest Private Hospital, Sydney, NSW, Australia; [5]Department of Neurosurgery, St Vincent's Private Hospital, Melbourne, VIC, Australia; [6]Department of Neurosurgery, Epworth Hospital, Melbourne, VIC, Australia; [7]Department of Neurosurgery, Monash Medical Centre, Melbourne, VIC, Australia; [8]Department of Surgery, University of Melbourne, Melbourne, VIC, Australia

Contributions: (I) Conception and design: B Owler, YY Wang, I Sher, B Dawes; (II) Administrative support: B Owler, YY Wang; (III) Provision of study materials or patients: B Owler, YY Wang; (IV) Collection and assembly of data: VS Rajkumar; (V) Data analysis and interpretation: VS Rajkumar; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Vijidha Shree Rajkumar, B.Sc. (Hon), M.Sc., MD. O Spine, Q Building, Suite 312, 10 Norbrik Drive, Bella Vista, Sydney, NSW 2153, Australia; Department of Neurosurgery, Sydney Adventist Hospital, 185 Fox Valley Rd., Wahroonga, Sydney, NSW 2076, Australia. Email: vraj8235@uni.sydney.edu.au.

Background: Prone transpsoas (PTP) fusion is a single-position variant of direct transpsoas interbody reconstruction that is increasing in popularity in Australia. This technique provides simultaneous access to the anterior and posterior columns while maintaining the familiar prone position and utilising position-specific equipment. However, major vascular, visceral, and neurological complications associated with the procedure remain a concern for spine surgeons. Our study aims to elucidate the safety profile of PTP fusion among early adopters in Australia.

Methods: Australian surgeons interested in the PTP approach underwent surgical education and training prior to their first PTP procedure. All PTP-trained surgeons were invited to participate in the study through an online survey of 14 questions querying their PTP experience. Of the 20 PTP-trained surgeons, 16 responded to the survey, representing 293 out of 327 PTP surgeries completed in Australia from March 2023 to May 2024.

Results: The survey was completed by 16 surgeons (80%) from the Australian PTP community, encompassing 293 PTP surgeries (90%) completed. The surgeon cohort reported no major vascular or visceral complications. There are two cases (0.68%) of weakness of the psoas muscle, two cases (0.68%) of sustained motor deficits, and four cases (1.37%) of sensory deficits. Additionally, there are two cases (0.68%) of vertebral fractures or implant subsidence requiring re-operation and four cases (1.37%) of surgical site infections.

Conclusions: Our study shows the successful establishment of PTP procedure following a PTP surgical training model. The survey's high response rate reinforces the low complication rates encountered by our surgeons and adds to the safety profile of this novel procedure. Additionally, it underscores the significance of surgical education and training opportunities in minimally invasive spinal fusion techniques.

Keywords: Prone transpsoas (PTP); training; early adopters; complications; single-position prone interbody fusion

^ ORCID: 0000-0002-4770-9055.

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Introduction

Spinal fusion surgery is indicated in various clinical presentations of spinal instability, degenerative disc disease, recurrent disc prolapses, spinal deformity, and spinal stenosis (1-4). For minimally invasive spinal fusion procedures, interbody fusion of the anterior column is the mainstay of achieving solid union. The key advantages of placement of a large footprint interbody cage, resting on the cortical rim, include the achievement of sagittal and coronal plane correction, indirect decompression through ligamentotaxis, and restoration of disc height (5,6). High rates of spinal fusion are thus achieved through the placement of these larger cages via an anterior (ALIF), oblique (pre-psoas, OLIF), or lateral (LLIF) decubitus transpsoas lumbar interbody fusion approach (7,8).

Despite the perceived advantages of the LLIF approach, it is estimated only 20% of spinal surgeons across Australia have adopted the approach since its inception in the early 2010s (9,10). Detractors of the approach raise concerns about the safety of the surgical corridor through the retroperitoneal space, with reports of major vessel injuries resulting in catastrophic outcomes (3,11,12). Similar concerns have been raised regarding the risk to peritoneal and retroperitoneal structures, including rare reports of renal, ureteric, and bowel injuries in literature (13,14). Lastly, there have been concerns regarding the potential for injury to the lumbosacral plexus; however, the reported incidence of permanent neurological deficits is only 1–2% (15,16). Indeed, the incidence of neurological deficits from the largest Australian study in 2023 reported less than 1% permanent neurological issues at the final follow-up (17). Despite reports of single-position LLIF surgery with the patient in the lateral decubitus position (18), posterior fixation remains technically challenging, and patient repositioning to the prone position is commonly performed.

The prone transpsoas (PTP) approach, published in 2020, has been implemented in the United States for years (19). Specifically, PTP is unique to prone lateral surgery in utilising proprietary designed retractors, patient positioners, SafeOp neuromonitoring, and surgical instruments by AlphaTec (ATEC) Spine (Carlsbad, CA, USA). The premise of the PTP approach is to perform LLIF with the patient positioned in the prone rather than in the lateral decubitus position, utilizing position-specific instruments. Benefits are purported to be the familiarity of the position for spinal surgeons, allowing for true single-position surgery, and simultaneous access to the anterior and posterior columns with a physiologically or naturally lordotic patient positioning. Additionally, there are reported benefits of the anatomical changes within the surgical corridor of access through the retroperitoneal space in the prone position (20). The complication profile of the PTP approach has been reported to be comparable to the LLIF approach in experienced surgeons; however, there is no data regarding this for new adopters of the PTP approach (21,22).

In Australia, the PTP approach by ATEC became available in March 2023. Interested spinal surgeons receive surgical education and procedure-specific training that follows an educational protocol. This study aimed to investigate the prevalence of major complications across the entire cohort of PTP-trained surgeons through an online survey. Through analysis of the early outcomes from these surgeons, this study aims to better elucidate the risk profile

Highlight box

Key findings

- An Australian survey of early adopters of prone transpsoas (PTP) fusions, with 80% survey uptake, reports no major vascular or visceral complications among the 293 PTP procedures, representing 90% of the country's caseload.

What is known and what is new?

- Previous studies on complications associated with direct lateral transpsoas fusions have documented major vascular and visceral complications, as well as varying rates of persistent neural injuries.
- Our study reports no major vascular or visceral complications from this minimally invasive spinal fusion approach and 0.68% of sustained motor injuries. This study adds to the safety profile of PTP fusions.

What is the implication, and what should change now?

- Further prospective studies with extended follow-up data are needed to clarify the long-term outcomes of PTP procedures. Developing robust education and training models may help lessen early learning curves associated with new minimally invasive spinal procedures and improve overall safety.

of the PTP procedure among its early adopters. It also highlights a market for optimizing the learning curves of surgeons with education and training in minimally invasive spinal procedures. We present this article in accordance with the STROBE reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-24-128/rc).

Methods

PTP training

The PTP approach for this study is defined as lateral interbody fusion in the prone position utilising the proprietary patient positioners, SafeOp neuromonitoring, and specific PTP retractor as developed and trademarked by ATec Spine. Mainly, surgeons commencing PTP surgeries in Australia were subjected to a training and education program before their first PTP surgery, which spanned several parts. Firstly, a lecture-based didactic series was given, including a detailed explanation of the clinical indications, surgical approach, and proprietary instrumentation by a trained PTP educator. Where practical, a hands-on cadaveric laboratory session was then held, allowing the new adopter to perform a PTP across several levels, thereby gaining experience in the imaging characteristics and nuances of the surgical instrumentation. Lastly, the trained PTP surgeons had the opportunity to be proctored by trained surgeon proctors, either through site visitation for live surgery education or reverse site visitation, whereby the proctor surgeon assists in the initial few cases of PTP performed by the new adopter.

Data were included from each surgeon's entire series of PTP patients starting from their first procedure.

PTP technique

Patients undergoing PTP were administered a total intravenous anaesthetic to allow for intra-operative neuromonitoring, including continuous somatosensory evoked potentials (SSEPs) monitored via needle electrodes placed in the lower limbs and scalp. The patient was positioned prone over the patient positioners and secured tightly through the apposition of lateral pelvic and thoracic positioners.

The image intensifier (II) was then used to mark the skin incision on the lateral flank over the targeted disc space. Following routine anti-septic skin prepping and draping, the lateral incision was opened, and access to the retroperitoneal space is achieved through direct vision and splitting of the three layers of the lateral abdominal wall. The retroperitoneal space is accessed, and the psoas muscle is directly palpated to guide dilator placement. Neuromonitoring is used to assess directional triggered electromyography (tEMG) during the placement of sequential dilators. Then, the lateral retractor is positioned and opened in the anterior-posterior direction and secured with anterior and posterior shims under fluoroscopy.

A standard discectomy is performed, and endplates are cleared with curettes. Trialing is then conducted to size an appropriate cage, which is placed under direct fluoroscopy. The retractor is then removed, and the lateral incision is closed while the posterior portion of the surgery is commenced, if required.

Cross-sectional survey

A cross-sectional survey created in SurveyMonkey comprising 14 questions (*Figure 1*) was sent via email to all trained PTP surgeons in Australia, with no minimum case requirement. Two subsequent follow-up reminders were sent at one- and two-week intervals following the initial request. The survey focused on surgical experience, including the duration and extent of prior LLIF (non-PTP) experience, the extent of PTP experience, and a binary yes/no response regarding major complications. Operational records were used to verify the number of PTP cases reported by each respondent, and in cases of discrepancy, the lower number was recorded.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All participants of the study voluntarily give informed consent for analysis and publication of the data for public access.

Statistical analysis

The data was collated from the operational record and SurveyMonkey and subsequently recorded into an Excel spreadsheet for analysis. The continuous variables summarizing surgeon experience and cases were analysed with Excel equation functions to describe the median, interquartile range (Q1; Q3), mean, standard deviation (SD), and the range as minimum and maximum raw values. The complication rates are represented as raw values and as a percentage of the total case volume reported in this survey. The correlation between surgeons' experience and complication rates from the PTP cases are computed with

1.	Did you (the surgeon) have prior LLIF (lateral decubitus) experience before PTP?
2.	If you answered yes to Question 1, please specify number of years/cases
	- Years
	- Cases
3.	How many PTPs have you performed?
	Of the PTPs you have performed, how many patients have experienced a complication, specifically:
4.	Major vascular (great vessel) injury?
5.	Urinary tract injury?
6.	Renal injury?
7.	Bowel injury (including peritoneal injury)?
8.	Lung injury (including pleural injury)?
9.	Weakness of psoas muscle (>3 months)?
10.	Motor deficit (>3 months)?
11.	Sensory deficit (>3 months)?
12.	Vertebral fracture and/or iatrogenic subsidence (requiring reoperation)?
13.	Surgical site infection (SSI)?
14.	Other complications (please specify)

Figure 1 PTP survey questions. LLIF, lateral lumbar interbody fusion; PTP, prone transpsoas fusion.

Table 1 Summary of PTP case numbers and survey response rates in Australia (March 2023–May 2024)

PTP	Survey/AUS [%]
Case	293/327 [90]
Surgeons	16/20 [80]

AUS, Australia-wide national data; PTP, prone transpsoas fusion.

Table 2 Summary of statistics on previous surgical experience of the survey responders (questions 1 & 2)

Descriptive statistics	Previous LLIF experience	
	Years	Cases
Cumulative total	111	2,290
Range (Min–Max)	0–15	0–800
Median [IQR]	8 [4; 10]	45 [35; 150]
Mean (SD)	6.94 (4.45)	143.13 (219.41)

IQR, interquartile range; LLIF, lateral lumbar interbody fusion; Max, maximum; Min, minimum; SD, standard deviation.

Excel linear regression analysis to yield the correlation coefficient and its significance as P value.

Results

Twenty surgeons underwent training for the PTP approach over the survey period, with all trained surgeons performing at least one PTP following their training. Sixteen surgeons (80%) responded to the survey accounting for 293 (90%) out of the 327 total PTP cases performed in Australia since inception (*Table 1*).

Of the 16 surgeons, two (13%) reported no previous lateral transpsoas spinal experience. The remaining 14 surgeons (87%) have an average of 6.94 (SD, 4.45) years of experience in LLIF surgeries (*Table 2*). Among the 16 surgeons, 7 (44%) are experienced LLIF surgeons, having completed more than 50 LLIF cases prior to PTP training. One of the surgeons also had previous prone lateral interbody fusion experience, having completed over 20 cases before commencing the PTP approach

Table 3 Summary of surgical experience and complications from survey responders in Australia

Surgeon	LLIF experience		PTP cases		Injuries		Deficits >3 months			Complications	
	Years	Cases	Estimated	Power BI	Major vascular (great vessels)	Visceral (lung/bowel/renal/urinary tract)	Psoas muscle weakness	Motor	Sensory	Vertebral fracture/iatrogenic subsidence	Surgical site infection
1	2	10	3	2	0	0	0	0	0	0	0
2	9	40	11	15	0	0	1	1	1	0	0
3	6	40	3	3	0	0	0	0	1	0	0
4	0	0	2	2	0	0	0	0	0	0	0
5	10	80	4	4	0	0	0	0	0	0	0
6	0	0	1	1	0	0	0	0	0	0	0
7	4	50	3	4	0	0	1	1	0	0	0
8	14	300	30	17	0	0	0	0	0	0	0
9	10	60	1	1	0	0	0	0	0	0	0
10	4	40	30	29	0	0	0	0	1	0	1
11	8	500	5	3	0	0	0	0	0	0	0
12	7	200	125	120	0	0	0	0	0	0	1
13	10	30	26	23	0	0	0	0	0	1	1
14	4	40	4	4	0	0	0	0	1	0	1
15	15	800	1	1	0	0	0	0	0	1	0
16	8	100	65	64	0	0	0	0	0	0	0
Total (%)	–	–	314	293	0	0	2 (0.68)	2 (0.68)	4 (1.37)	2 (0.68)	4 (1.37)

BI, business intelligence; LLIF, lateral lumbar interbody fusion; PTP, prone transpsoas fusion.

described above. Among the experienced LLIF cohort, two complications were reported from their PTP cases: one instance of delayed subsidence requiring re-operation and one surgical site infection (*Table 3*). For the entire cohort, no major vascular or visceral injuries were reported among the 293 PTP cases (*Table 3*). There were two cases (0.68%) of weakness of the psoas muscle, two cases (0.68%) of sustained motor deficits including psoas and quadriceps weakness, and four instances (1.37%) of sensory deficits greater than three months at completion of the study period (*Table 3*). Two cases (0.68%) of vertebral fractures or implant subsidence were reported requiring re-operation. One case had cranial subsidence (inferior endplate) at the time of surgery secondary to bone quality and underwent an elective extension of fusion. The other is the case of delayed subsidence described above. Cumulatively there were four cases (1.37%) of surgical site infections. Specifically, two cases (0.68%) are from posterior incisions for pedicle screw placement or decompression, while the other two (0.68%) cases involved superficial wound infections that required oral antibiotics for treatment. In the open-ended responses regarding miscellaneous complications, reports include aborted procedures due to neural anatomy, cerebral spinal fluid (CSF) leaks from posterior decompressions, and other medical complications (*Table 4*).

Linear regression models demonstrate no statistically significant correlation between surgeon experience in LLIF and complications in PTP. Specifically, there was no significant correlation between prolonged neurological complications, post-operative muscle weakness, vertebral fractures, subsidence, or surgical site infections and the surgeons' previous LLIF experience (*Table 5*).

A summary of complication rates from published literature is compared to the rates reported in this survey study (*Table 6*).

Discussion

PTP is a single-position variant of direct transpsoas interbody fusion. A key advantage of PTP is its combination

Table 4 Summary of miscellaneous complications

Surgeon	Open-ended responses for other complications
2	Femoral nerve palsy
7	Abandoned case, unable to access disc safely
8	CSF leak—from redo laminectomy, not related to PTP directly
10	Superficial wound infection requiring oral antibiotics
12	New post-operative atrial fibrillation (×1), delirium (×2) post long constructs posteriorly/infection, acute myocardial infarction (×1)
13	1 small psoas haematoma, managed conservatively with analgesia, no neurological compromise. SSI from the posterior MIS screw incision, not from the lateral PTP incision site
14	Superficial wound infection requiring oral antibiotics
16	Abandoned due to neural structure preventing safe access on the left, successfully completed procedure through a right-sided approach

CSF, cerebral spinal fluid; MIS, minimally invasive spine; PTP, prone transpsoas fusion; SSI, surgical site infection.

Table 5 Summary of correlation analysis between previous surgical experience in LLIF and PTP complications

Complications	LLIF experience	
	Years	Cases
Psoas weakness (>3 months)	–0.04	–0.17
Motor deficit (>3 months)	–0.04	–0.17
Sensory deficit (>3 months)	–0.16	–0.28
Surgical site infection	–0.09	–0.19
Vertebral fracture and/or iatrogenic subsidence requiring reoperation	0.49 (P=0.06)	0.48 (P=0.89)

LLIF, lateral lumbar interbody fusion; PTP, prone transpsoas fusion.

Table 6 Comparison of major complications reported for direct lateral fusions studies *vs*. Australian PTP survey results

Article (author & year)	Type of study	Surgical approach	Complication rates					
			Vascular (%)	Visceral (%)	Transient neurological injury (%)	Persistent motor neurological injury (%)	Subsidence/ vertebral fractures (%)	Wound infection (%)
Hijji *et al.* [2017] (14)	Systematic review of 63 studies	LLIF	0.81	0.93–1.47	36.07	3.98	0.8–6.61	1.38
Walker *et al.* [2019] (15)	Systematic review and meta-analysis of 58 transpsoas studies	LLIF	0.4	1.3	21.7	2.8	13.8	3.1
Farber *et al.* [2023] (21)	Systematic review of 10 studies	Prone LLIF	Nil	Nil	13.3	1.2	3.8	1.9
Soliman *et al.* [2023] (22)	Retrospective multi-centre cohort study of 365 patients	PTP	0.3	0.3	5.8–8.2	N/A	0.8	1.4
Wellington *et al.* [2023] (23)	Retrospective cohort study of 82 patients	PTP	Nil	Nil	2.4–7.3	1.2	1.2	N/A
Van Pevenage *et al.* [2024] (24)	Prospective single-centre cohort study of 120 patients	PTP	Nil	Nil	10–12	0.8	0.8	0.8
Our study	Survey of 293 PTP cases	PTP	Nil	Nil	N/A	0.68	0.68	1.37

LLIF, lateral lumbar interbody fusion; N/A, not available; PTP, prone transpsoas fusion.

of familiar prone positioning with proprietary instruments and retractors specifically designed for this approach, allowing access to both the anterior and posterior columns from a single ergonomic stance. Additionally, it offers the benefits of LLIF with the placement of a large footprint cage in the anterior column, which enhances segmental lordosis and achieves indirect decompression by restoring intervertebral disc height. The minimally invasive nature of this technique also reduces wound healing requirements (25). This approach, published by Pimenta and Taylor [2020] (19), has gained interest from early adopters for these reasons, although concerns remain regarding its safety profile (22).

Our survey demonstrates low rates of major complications during the establishment of PTP in Australia. More specifically, there are no reported cases of major vascular, bowel, renal, urinary tract, lung, or other visceral complications among the 293 cases covered in this survey. There are two cases (0.68%) of psoas muscle weakness, and of motor deficits, including quadriceps weakness, lasting more than three months, as well as four cases (1.37%) of sensory deficits. These rates compare favorably to existing literature from previous studies on prone and lateral lumbar interbody spinal fusion approaches. Previous studies surveying surgical experience and complication rates for LLIF cases in Japan by Yagi *et al.* [2022] (26), in Italy by Piazzolla *et al.* [2021] (27), the SOLAS group by Uribe *et al.* [2015] (12), and more recently, for the early adopters of the PTP approach by Pimenta *et al.* [2024] (28) discussed major vascular, visceral, and neurological complication rates encountered by surgeons. Of these, the complication rates for vascular and visceral injuries among surgeons surveyed for the LLIF approach ranged from 0.10% to 0.17% and 0.08% to 0.20%, respectively, with a survey response rate of 39% to 53%. Additionally, the Japanese survey reported a 0.43% rate of persistent motor deficits and a 0.50% rate of sensory deficits lasting over three months. In the only published survey of PTP adopters, the rates were 0.05% for vascular injuries, 0.05% for visceral injuries, and 0.66% for persistent motor deficits lasting more than one month, based on a total of 1,963 cases and a 64% survey response rate.

In addition to the surveys mentioned above, other published data report varying incidences of vascular, visceral, and neurological complications in minimally invasive transpsoas spinal fusions (14,15,21). Moreover, there are three studies focus on PTP-specific complications (22-24). The Australian data from this survey are comparable to, if not better than, the previously established complication rates for transpsoas approaches via both the lateral decubitus and prone positions (*Table 6*). Pimenta *et al.* [2023] illustrated the risk of injury to the retroperitoneal structures in the prone position to be much lower than in the lateral position (29). Furthermore, studies have shown dorsal migration of the femoral nerve at L4–L5 disc space (30), as well as the less anterior location of psoas muscle and vessels (31) in the prone versus lateral decubitus, favouring prone positioning for transpsoas approach. This, combined with the natural lordotic curvature of prone patients, highlights the advantages of prone single-position surgery. However, while gravity enhances lumbar lordosis in this position, it may also affect the retractor system, contributing to the ventral migration of retractors during the procedure. A single-center study by Patel *et al.* [2023] identified this retractor migration as a significant factor in the early learning curve of prone LLIF (32). Likewise, Warren *et al.* [2021] emphasized the challenges faced during the establishment of a single-position lateral transpsoas approach combined with pedicle screw fixation in the lateral decubitus position (33). Similarly, all surgeons commencing PTP surgeries in Australia underwent a learning curve. The use of prone-specific instrumentation, particularly the two-shim model, along with a training program facilitated by a trained PTP proctor during the surgeon's initial cases, helped reduce this learning curve for early adopters in Australia.

The strength of this survey is the establishment of a novel procedure in Australia, with a high response rate of 80%, covering 90% of the country's PTP caseload. The study's limitations include recall bias and response rate biases from surgeons. Furthermore, the complication rates reported here comprise of a select group of surgeons interested in PTP training, and thus, this data might not allow for extrapolation to a wider surgeon population.

Conclusions

In summary, this survey illustrates the major complications encountered during the early adoption of the PTP fusion technique in Australia. The successful establishment of the PTP procedure followed a structured education and training protocol. The low complication rate reported in this study provides insight into the benefits of training for minimally invasive techniques and the market for such opportunities. It also serves to add to the safety profile of this novel procedure. While further comprehensive studies are required to validate and replicate the findings, the early results from Australia are encouraging for the PTP approach.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jss.amegroups.com/article/view/10.21037/jss-24-128/rc

Data Sharing Statement: Available at https://jss.amegroups.com/article/view/10.21037/jss-24-128/dss

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All participants of the study voluntarily give informed consent for analysis and publication of the data for public access.

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