Unintended durotomy in lumbar degenerative spinal surgery: a 10-year systematic review of the literature

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OBJECT Unintended durotomy is a common occurrence during lumbar spinal surgery, particularly in surgery for degenerative spinal conditions, with the reported incidence rate ranging from 0.3% to 35%. The authors performed a systematic literature review on unintended lumbar spine durotomy, specifically aiming to identify the incidence of durotomy during spinal surgery for lumbar degenerative conditions. In addition, the authors analyzed the incidence of durotomy when minimally invasive surgical approaches were used as compared with that following a traditional midline open approach.

METHODS A MEDLINE search using the term “lumbar durotomy” (under the 2015 medical subject heading [MeSH] “cerebrospinal fluid leak”) was conducted on May 13, 2015, for English-language medical literature published in the period from January 1, 2005, to May 13, 2015. The resulting papers were categorized into 3 groups: 1) those that evaluated unintended durotomy rates during open-approach lumbar spinal surgery, 2) those that evaluated unintended durotomy rates during minimally invasive spine surgery (MISS), and 3) those that evaluated durotomy rates in comparable cohorts undergoing MISS versus open-approach lumbar procedures for similar lumbar pathology.

RESULTS The MEDLINE search yielded 116 results. A review of titles produced 22 potentially relevant studies that described open surgical procedures. After a thorough review of individual papers, 19 studies (comprising 15,965 patients) pertaining to durotomy rates during open-approach lumbar surgery were included for analysis. Using the Oxford Centre for Evidence-Based Medicine (CEBM) ranking criteria, there were 7 Level 3 prospective studies and 12 Level 4 retrospective studies. In addition, the authors also included 6 studies (with a total of 1334 patients) that detailed rates of durotomy during minimally invasive surgery for lumbar degenerative disease. In the MISS analysis, there were 2 prospective and 4 retrospective studies. Finally, the authors included 5 studies (with a total of 1364 patients) that directly compared durotomy rates during open-approach versus minimally invasive procedures. Studies of open-approach surgery for lumbar degenerative disease reported a total of 1031 durotomies across all procedures, for an overall durotomy rate of 8.11% (range 2%–20%). Prospectively designed studies reported a higher rate of durotomy than retrospective studies (9.57% vs 4.32%, $p = 0.05$). Selected MISS studies reported a total of 93 durotomies for a combined durotomy rate of 6.78%. In studies of matched cohorts comparing open-approach surgery with MISS, the durotomy rates were 7.20% (34 durotomies) and 7.02% (68), respectively, which were not significantly different.

CONCLUSIONS Spinal surgery for lumbar degenerative disease carries a significant rate of unintended durotomy, regardless of the surgical approach selected by the surgeon. Interpretation of unintended durotomy rates for lumbar surgery is limited by a lack of prospective and cohort-matched controlled studies.

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KEY WORDS lumbar spine; durotomy; cerebrospinal fluid leak; complications; trauma; thoracolumbar

UNINTENDED durotomy is a common occurrence during lumbar spinal surgery for degenerative spinal indications, and rates of durotomy can range from as low as 0.3% in lumbar discectomy²⁶ to 35% in an isolated study involving instrumented fusions for lumbosacral

spondylolisthesis.³³ The overall incidence is reported to be approximately 17% across all spinal indications and regions.¹ A number of factors have been cited for increasing risk of durotomy during lumbar surgery, including revision surgery,^{14,43} lumbar degenerative indications relative to op-

ABBREVIATIONS BMI = body mass index; MISS = minimally invasive spine surgery; PLIF = posterior lumbar interbody fusion; TLIF = transforaminal lumbar interbody fusion.

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erating at the cervical or thoracic level,²⁰ diabetes,³¹ age,¹⁷ obesity, and surgical-invasiveness score.^{3,6,20,43} Moreover, some studies suggest that unintended durotomies will occur regardless of the surgeon's prior experience.³¹

Unintended durotomy can result in neurological deficit because of the proximity of the neural tissue and the dural sleeve.⁴³ However, neurological deficit does not always occur, as Wang et al. noted no instances of neural damage resulting from unintended durotomy during lumbar spinal surgery in a large retrospective study of 641 patients.⁴³ Several comorbidities have been reported to occur after an unintended durotomy including spinal headaches,³⁴ pseudomeningocele,¹⁸ meningitis,²⁴ and nerve root entrapment resulting in intractable pain.¹ Despite these morbidities, the occurrence of an unintended durotomy has been shown in prospective studies to have no significant impact on patient functional outcomes, postoperative complications, and pain¹ and that persistent CSF leaks are manageable with good results.⁴³

"Open" or traditional surgical approaches rely on a traditional midline subperiosteal dissection, with resulting elevation and retraction of the paraspinal musculature to expose the posterior elements of the spine. A meta-analysis performed by Zhang and colleagues reported that variations in open approaches to the posterior lumbar interbody space can influence the rate of unintended durotomy.⁴⁶ Specifically, transforaminal lumbar interbody fusion (TLIF) procedures had a significantly lower durotomy rate as compared with posterior lumbar interbody fusion (PLIF), which is a more medial approach.⁴⁶ However, one drawback to making interpretations based on literature reviews is that lumbar surgical approaches and complication rates are evaluated based on a heterogenic population and multiple studies; there is a lack of randomized clinical trials and thus a high reliance on retrospective studies.⁴⁶

Minimally invasive spine surgery (MISS) refers to a modification of the traditional approach that minimizes muscle manipulation, soft tissue dissection, pain, and blood loss.²⁷ The confusion between MISS and open spinal surgery is that these divisions have the same aforementioned overarching goals and that "minimally" or "less invasive" surgery can be described as a philosophy more than a specific set of procedures. In general, percutaneous, endoscopic, and keyhole approaches using trocars or tubular retractors often involve smaller incisions from an approach lateral to the midline in an attempt to minimize trauma, retraction, and devascularization of the posterior soft tissues, which can be associated with pain, blood loss, narcotics use, and prolonged hospital stays.

The aim of this study was to analyze unintended durotomy in the medical literature in order to clarify the incidence of durotomy during lumbar spinal surgery and to compare the rates of durotomy in studies with MISS and open-approach cohorts.

Methods

A MEDLINE search using the term "lumbar durotomy" (under the medical subject heading [MeSH] "cerebrospinal fluid leak") was conducted on May 13, 2015, to

evaluate the English-language medical literature for pertinent studies relating to unintended durotomy that were published in the period from January 1, 2005, to May 13, 2015. Two authors (G.M.G. and T.T.) reviewed the titles of papers that were returned in the initial search to determine if the papers were pertinent to a durotomy encountered during lumbar spinal surgery for common degenerative spinal indications. Articles that were pertinent and those that were unclear in the initial search were included for further review. After a detailed review of the abstract, individual papers were evaluated for final inclusion in the data analysis, and the bibliographies were collected.

Inclusion Criteria

The reviewed literature included retrospective and prospective studies whose levels of evidence were classified as Levels 1–4 according to the Oxford Centre for Evidence-Based Medicine (CEBM) ranking criteria. Relevant papers were selected for inclusion in the systematic review based on a detailed analysis of the title, abstract, and body text.

Exclusion Criteria

Meta-analyses, systematic reviews, editorials, case reports, and case series with less than 10 patients were excluded. Case series not entirely composed of patients undergoing lumbar spinal surgery were also excluded. Lumbar surgery indications other than common degenerative indications were excluded, including spinal neoplasm surgery, scoliosis, and other deformity-correction procedures. In addition, we excluded laboratory or animal research studies, non-English publications, commentaries, descriptive studies, technical notes, and those articles deemed irrelevant.

Outcome, Review, and Analysis by Surgical Approach

Papers were categorized by surgical procedure into 3 discrete groups for further analysis: 1) surgical series involving only open-approach lumbar procedures, 2) studies involving MISS only, and 3) studies of comparable cohorts that underwent open spine surgery or MISS for similar degenerative lumbar pathology. The primary outcome was unintended durotomy during lumbar spine surgery. Study analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.¹² A Student t-test was used to compare rates of durotomy between open spine surgery and MISS using a statistical software analysis package designed for use with Microsoft Excel 2010, version 14.0.7149.5000.

Definitions of MISS

The procedures for minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF), minimally invasive posterior lumbar interbody fusion (MIS-PLIF), and discectomy were performed according to commonly described lumbar decompression and fusion techniques previously described, notably by Foley and colleagues.^{11,16} The aforementioned procedures were classified as minimally invasive if they involved a paramedian incision and

FIG. 1. Flow diagram of study selection.

tubular or multiple-blade retractor systems with the intention of limiting approach-related morbidity.

Results

An advanced MEDLINE search for lumbar durotomy yielded 116 results. After reviewing the paper titles and utilizing our inclusion and exclusion criteria, 22 potentially relevant studies on open surgical procedures remained for detailed analysis. This number was further refined to 19 studies (comprising 15,965 patients) after we limited our analysis to those studies focused on open approaches for lumbar surgery (Fig. 1). In total, our studies for open-approach surgery consisted of 7 prospective studies and 12 retrospective studies (Table 1).

Six studies (comprising 1334 patients) were analyzed for durotomy occurrence during minimally invasive lumbar surgery for degenerative disease (Table 2). There were 2 prospective and 4 retrospective studies. Finally, 5 studies (comprising 1364 patients) were analyzed for direct comparison of durotomy rates in matched cohorts of patients who underwent open versus minimally invasive procedures for similar lumbar pathology (Table 3).

Durotomy Rate

Studies involving open surgical procedures performed for lumbar degenerative disease reported a total of 1031 durotomies across all procedures for an overall durotomy incidence of 8.11% (range 2%–20%). Prospectively designed studies reported a higher durotomy rate than retrospective studies (9.57% vs 4.32%, $p = 0.05$). Studies se-

lected for analysis of MISSs included a total of 93 durotomies for an overall durotomy rate of 6.78%. In studies of matched cohorts comparing open surgery and minimally invasive approaches, the durotomy rates were 7.20% (34 durotomies) and 7.02% (68), respectively, which were not significantly different.

Discussion

The frequency of lumbar surgery for the treatment of patients with degenerative spinal indications is increasing, and studies of the Nationwide Inpatient Sample have shown that the number of procedures,⁴⁵ specifically for lumbar degenerative indications, has doubled in the last decade. With this increased volume of lumbar operations and the increased fusion rate, the impact of durotomy recognition and management becomes increasingly important.

Open Lumbar Procedures

The reported rates of durotomy in studies of open-approach procedures for lumbar degenerative conditions were not insignificant; a total of 1031 durotomies were reported, for a rate of 8.11% (range 2%–20%; Table 1). Surgical invasiveness and manipulation of the dura have been reported as a general predictors³ of durotomy and appeared to correlate with overall durotomy rates. One retrospective study by Sofianos et al. analyzed complications of lateral lumbar interbody fusions, which are performed away from the dura, and found a 2% durotomy rate.³⁹ The durotomy rates in studies entirely composed

TABLE 1. Selected studies for analysis of open-approach procedures

Authors & Year	Type of Study	No. of Patients	Lumbar Procedure (n)	Incidence of Durotomy (n)	Durotomy Rate	Risk Factor Identified
Smorgick et al., 2015	Prospective cohort	523	Discectomy (131), laminectomy (392)	55	10.5%	Prior lumbar surgery
Desai et al., 2015	Prospective cohort	439	Laminectomy +/- fusion	37	9%	NA
Chen et al., 2015	Retrospective	2184	Unspecified	101	4.62%	Prior lumbar surgery, older age
Bydon et al., 2015	Retrospective	327	Lumbar posterolateral fusion	17	5.19%	NA
Blecher et al., 2014	Retrospective	1235	Unspecified	84	6.8%	NA
Adogwa et al., 2014	Prospective	1741	Lumbar fusion	70	4.0%	NA
Low et al., 2013	Retrospective	889	Unspecified	61	6.8%	NA
Takashi et al., 2013	Retrospective	1014	Multimodal	40	4.0%	Female sex, older age, degen spondy, juxtafacet cysts
Desai et al., 2013	Retrospective	793	Lumbar laminectomy +/- fusion	78	9.8%	NA
Desai et al., 2012	Prospective	792	First time lumbar discectomy	25	3.0%	NA
Baker et al., 2012	Prospective	1745	Multimodal	161	10.0%	Revision surgery
Tormenti et al., 2012	Retrospective	531	TLIF	76	14.3%	Revision surgery, multilevel TLIF
Desai et al., 2013	Prospective	389	Decompressive laminectomy	41	10.5%	NA
Sofianos et al., 2012	Retrospective	45	Lateral transposas approach	1	2.0%	NA
Guerin et al., 2012	Retrospective	1326	Multimodal	48	3.61%	NA
Mehta et al., 2011	Retrospective	119	PLIF (76), TLIF (43)	17	14.2%	PLIF
Kalevski et al., 2010	Retrospective	553	Multimodal	70	12.6%	Revision surgery, spinal trauma
Rodriguez-Olaverri et al., 2008	Prospective	40	Unilateral TLIF, transvertebral screw fixation	8	20.0%	NA
Saxler et al., 2005	Retrospective	1280	Lumbar discectomy	41	3.2%	NA

degen spondy = degenerative spondylosis; NA = not applicable.

of open-approach decompression without fusion ranged from 3.2% with discectomy alone³⁶ to 10.5% in a series by Smorgick et al. in which approximately one-third of the patients had undergone prior spinal surgery. The durotomy incidence in a group of patients who underwent revision surgery was 25% (29 of 116) and was not associated with the years of experience of the surgeon performing the procedure.³⁸ Studies entirely composed of interbody fusion procedures, such as those conducted by Mehta et al.²⁸ and Tormenti et al.,⁴² reported higher durotomy rates of

14.2% and 14.3%, respectively. The highest durotomy rate, 20%, was reported in a non-cohort-matched prospective study by Rodriguez-Olaverri and colleagues in which the authors evaluated clinical and radiographic outcomes of instrumented fusion for high-grade spondylolisthesis.³³

MISS Approaches

Minimally invasive approaches had an overall durotomy rate of 6.78%; this rate was calculated using the 6

TABLE 2. Reported durotomies for minimally invasive approaches for degenerative lumbar spinal surgery

Authors & Year	Study Type	No. of Patients	Minimally Invasive Procedure	Incidence of Durotomy (n)	Rate of Durotomy	Predictor of Durotomy
Wong et al., 2014	Retrospective	513	MIS-TLIF	26	5.1%	Multilevel MIS-TLIF
Tender & Serban, 2014	Retrospective	60	MIS-TLIF (tubular vs screw-based retractor technique)	3	5.0%	NA
Lee et al., 2012	Prospective cohort	90	Single-level MIS-TLIF	1	1.1%	NA
Nandyala et al., 2014	Prospective cohort	65	Single-level MIS-TLIF	4	6.1%	NA
Ruban & O'Toole, 2011	Retrospective	563	Multimodal MISS	53	9.4%	NA
Selznick et al., 2009	Retrospective	43	MIS-TLIF, MIS-PLIF	6	14.0%	Revision surgery

TABLE 3. Reported durotomy rates in selected studies using matched cohorts to compare open versus MISS techniques for lumbar degenerative disease

Authors & Year	Study Type	No. of Patients	Minimally Invasive Procedures (n)	Open Procedures (n)	No. of Durotomies		% Durotomies		Predictor of Durotomy
					MISS	Open	MISS	Open	
Kogias et al., 2015	Retrospective case-control	135	Tubular discectomy (53)	Open discectomy (82)	9	16	17.0%	19.5%	NA
Wong et al., 2014	Retrospective	863	Discectomy, foraminotomy, laminectomy (320)	Open version of MISS group (543)	15	49	4.7%	9.0%	Open surgery
Ang et al., 2015	Retrospective	113	Lumbar laminotomy (83)	Open version of MISS group (30)	3	0	3.6%	0.0%	NA
Lee et al., 2012	Retrospective	144	Single-level MIS-TLIF (72)	Open version of MISS group (72)	1	0	1.4%	0.0%	NA
Lee et al., 2011	Retrospective	109	Tubular discectomy (64)	Open discectomy (45)	6	3	9.3%	6.6%	NA

identified studies that primarily involved interbody fusion procedures, with the exception of 1 multimodal retrospective study by Ruban and O'Toole.³⁵ The durotomy rates were less interpretable in the lumbar MISS series because of limited numbers of patients and an undefined definition of durotomy. Thus, the reported incidence varied widely, ranging from 1% to 14%.^{22,37} Selznick and colleagues³⁷ reported a 14% durotomy rate in their series containing 43 MIS-TLIF and MIS-PLIF procedures. Although their study was limited by its retrospective design, no major complications attributed to these durotomies were reported, and nerve root injury, infection, and the need for any revision procedure to convert to open surgery were not described.³⁷ Almost all durotomies needed to be repaired by converting to an open approach.

Cohort-Matched Open Surgery Versus MISS Approaches

Matched-cohort studies published in the past 10 years were evaluated in an attempt to find more meaningful comparative data on durotomy rates in patients who underwent either open-approach or MISS procedures (Table 3). Five retrospective studies were selected. The durotomy rates did not significantly differ between MISS and open surgery cohorts, with overall rates of 7.20% (34 durotomies) and 7.02% (68), respectively. However, the total number of patients (1364) was limited, and background patient characteristics, such as body mass index (BMI), were not well matched in all studies, which can significantly impact durotomy rates.³ Wong and colleagues, who evaluated 863 patients undergoing 1- or 2-level decompression in a retrospective matched-cohort study, noted a significantly higher durotomy rate in the open surgery group versus the MISS group (9% vs 4.7%, $p = 0.01$).⁴⁴ To date, only 1 other cohort-matched study revealed a higher rate of durotomy in the open surgery category.³² In addition to the retrospective design, one major confounder in the Wong et al. study was the significantly higher percentage of revision surgery patients in the open surgery cohort (21.7% vs 16.0%, $p = 0.05$).

Numerous obstacles limit the interpretation of matched-cohort studies when comparing durotomy rates. A study by Wong et al. was performed in an institution where 37% of all decompressions over a 5-year period (320 of 863)

were MISS procedures.⁴⁴ This high volume of MISS procedures speaks to the technical proficiency of the surgeons contributing to this series, which in part could explain the lower durotomy rate. Furthermore, the standard selection markers for minimally invasive procedures favor choosing patients who have a relatively lower risk for durotomies, i.e., younger, undergoing nonrevision surgery, less degenerative spondylosis, and lower BMI. Moreover, studies evaluating complication rates of MISS over time have not yet revealed a significant difference in the durotomy rates, although a significant decrease in other intraoperative parameters have been observed.²⁹

Retrospective Versus Prospective Design

Study methodology remains a significant factor in measuring complication rates. Of the 19 open-approach studies selected, 12 were retrospective and 7 were prospective. Of the 7 prospective studies, only 5 were cohort-matched. The prospectively designed studies for open surgery procedures had over twice the durotomy rate (9.57%) as compared with retrospective studies (4.32%). The mix of procedures in the prospective patient category was well distributed between decompression alone and fusion, but other risk factors for durotomy such as number of decompression levels treated, patient age, obesity, and revision surgery were not tracked in all studies (Table 4). Despite this, the probable explanation for the lower durotomy rate in the retrospec-

TABLE 4. Summary of selected studies

Study Design	Total No. of Patients	Durotomy Rate	p Value
Retrospective	10,296	4.32%	0.05
Prospective	5669	9.57%	
MISS vs open surgery			
MISS cohort	592	7.2%	0.92
Open cohort	772	7.02%	
MIS: retrospective vs prospective			
Retrospective	1179	8.38%	0.26
Prospective	155	3.60%	

tive series is the inadequate study design that does not capture all complications. In a systematic review of posterior spine surgery approaches, Nasser and colleagues reviewed 105 articles with a total of 79,471 patients.³⁰ When evaluating posterior thoracolumbar procedures, they found a significantly higher complication rate in the prospective study group (20.4% vs 17.5%, $p < 0.0001$), which they attributed to data collection methodology.

Conclusions

Spinal surgery for lumbar degenerative disease carries a significant rate of unintended durotomy, regardless of whether the surgeon selects an open or minimally invasive surgical approach. Interpretation of unintended durotomy rates for lumbar surgery is limited because of a lack of prospective and cohort-matched controlled studies.

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Disclosure

Dr. Arnold is a consultant for Medtronic Sofamor Danek, Fzio-Med, SpineGuard, and Stryker Spine; owns stock in Z-Plasty; and has received reimbursed travel expenses from Stryker Spine and AOSpine. Dr. Darden is a consultant for Stryker, 4Web, and SpineGuard; owns stock in BioMedFlex; and has ownership in Stryker.

Author Contributions

Conception and design: Harrop, Ghobrial. Acquisition of data: Harrop, Ghobrial. Analysis and interpretation of data: Harrop, Ghobrial, Theofanis. Drafting the article: Ghobrial, Theofanis, Darden. Critically revising the article: Ghobrial, Darden, Arnold, Fehlings. Reviewed submitted version of manuscript: Harrop, Ghobrial. Statistical analysis: Ghobrial. Administrative/technical/material support: Ghobrial. Study supervision: Ghobrial.

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