To clarify outcomes and develop a novel classification according to CSF fistula in a selective cohort with intraoperative spinal dural tear, we examined 72 consecutive patients who underwent spinal dural repair after microdiscectomy (n=42) or lumbar spinal decompression (n=30). Group 1 consisted of 25 patients with Type I (mild) dural tear who were treated with either tissue-glue-coated collagen sponge or fibrin glue. Group 2 consisted of 26 patients with Type II (moderate) dural tear who were treated with both tissue-glue-coated collagen sponge and fibrin glue. Group 3 consisted of 21 patients with Type III (severe) dural tear who were treated with polypropylene suture along with tissue-glue-coated collagen sponge and/or fibrin glue. Evident postoperative internal or external CSF leak was used to determine the patient’s postoperative result. Postoperative internal or external CSF leak was not evident during a minimum 1-year follow-up in Group 1. In contrast, internal CSF leak was evident in both Groups 2 (n=3) and 3 (n=3) during the same follow-up. No external CSF leak was noted in any of the patients. Three patients underwent re-do spinal surgery for CSF leak repair. Patients in all groups satisfactorily avoided CSF leak. According to the intraoperative findings of a distinct dural tear, patients can be treated adequately with a specific surgical technique.
Spinal dural tear is a relatively common occurrence in lumbar procedures, and is treated by suture of the spinal dura, strict bed rest, fibrin glue, and lumbar drainage to prevent spinal CSF fistula. The morbidity associated with spinal CSF fistula is often accomplished using simple dural tears treated with microsurgery alone. For more complex cases, the treatment options are less appealing because they are associated with a higher morbidity rate. Previous studies have shown that potentially serious problems such as pseudomeningocele, CSF fistula, meningitis and arachnoiditis with subsequent chronic pain are all related to dural tears and CSF leakage after spinal surgery. Oversewing the wound with a running locked suture can sometimes stop a minor external leak in a relatively healthy patient. Lumbar drainage and blood patch have also been used in this situation. The success rates associated with different techniques vary, and depend on the patient and the spinal procedure itself. The early CSF fistula rates associated with the complete closure of intraoperative dural tears, which is often accomplished using suture and lumbar drain, are 3 and 7%, respectively. Strömqvist et al. reported a combined late morbidity rate of 7.4% for patients with intraoperative spinal dural tears. Unfortunately, little information is available about the selection of patients for treatment and the corresponding outcomes. In the current literature, the treatment of spinal dural tears, there is no grading system for comparing outcomes of different treatments or for predicting the associated rates of morbidity. The traditional indications for treatment are based on CSF fistula rates from studies on different types of spinal procedures, which precede the introduction of a specific grading system. The lack of a consensus in the literature and the potentially serious nature of this complication prompted us to further evaluate its incidence and management. The actual size of the lesion, as well as its location, which is often the most important factor, can determine the appropriate surgical technique for repair and the timing of the procedure. When dealing with relatively small dural tears, or those located at the nerve root shoulder or in the proximity of the dorsal surface of the dural sac, the surgical technique may be related to the specific anatomical type of the dural tear. Previously, we presented our preliminary results about a tailored technique for this complication. After broadening our experience, we now attempt to answer two relevant questions: are all spinal dural tears anatomically the same?, and for what kind of dural tears should we recommend bed rest, fibrin glue, suture or some combination?

The subjects were a consecutive series of patients who underwent elective spinal surgery for a lumbar herniated disc or spinal stenosis. The patients did not have previous lumbar surgery. Surgeries included microdiscectomy of the L3-L4 (n=5), L4-L5 (n=15) and L5-S1 (n=22) levels. Decompression of the lumbar spine included interlaminar decompression of the L3-L4 (n=3), L4-L5 (n=5) and L5-S1 (n=5), L3-L4 and L4-L5 (n=7), L4-L5 and L5-S1 (n=7) levels. Laminectomy of L5 was performed in the remaining three cases.

The intraoperative inclusion criteria for treatment of dural tear was persistent or excessive CSF exit from an iatrogenic tear of the dural sac, in either location, that was not controlled with standard techniques such as compression with use of cottonoids or when it was considered that these methods would be excessively time-consuming or could enlarge the dural tear. Visibility and potential nerve root damage were also considered. In each case, the decision to use a specific technique was made by a single surgeon according to their experience and the specific intraoperative dural tear. The primary end-point was defined as no CSF exiting from the dural sac after application of the specific technique.

Group 1 consisted of 25 patients with Type I (mild) dural tear, defined as

Figure 1. A Type I dural tear consists of disruption of the dura, with clean borders, minimal or no breach of the arachnoid, and the exit of only a few drops of CSF. These cases were intraoperatively treated with either fibrin glue or tissue-glue-coated collagen sponge.

Figure 2. A Type II dural tear consists of disruption of the dura, with clean borders, evident breach of the arachnoid, and the exit of multiple drops or a single line of CSF. The surgical technique included both tissue-glue-coated collagen sponge and fibrin glue.

Figure 3. A Type III dural tear consists of disruption of the dura, with more than one border, gross breach of the arachnoid sometimes with protrusion of the rootlets or nerve roots, and persistent exit of several lines of CSF. The technique for repair consisted of polypropylene suture along with tissue-glue-coated collagen sponge and/or fibrin glue.
disruption of the dura, with clean borders, minimal or no breach of the arachnoid, and exit of only a few drops of CSF (Fig. 1). These cases were intraoperatively treated with the application of fibrin glue or tissue-glue-coated collagen sponge.

Group 2 included 26 patients with Type II (moderate) dural tear, defined as disruption of the dura, with clean borders, evident breach of the arachnoid, and exit of multiple drops or a single line of CSF (Fig. 2). In these cases, treatment consisted of both tissue-glue-coated collagen sponge and fibrin glue.

Group 3 consisted of 21 patients with Type III (severe) dural tear, defined as disruption of the dura, with more than one border, gross breach of the arachnoid sometimes with protrusion of the rootlets or nerve roots, and persistent exit of several lines of CSF (Fig. 3). These cases were intraoperatively treated with polypropylene suture (Prolene® 5-0; Ethicon, Inc., Somerville, NJ) along with tissue-glue-coated collagen sponge and/or fibrin glue.

The following data were collected and analyzed for all patients: age, sex, diagnosis, location of the dural tear, surgical technique for repairing the dura, anatomical relation of the dural tear and duration of surgery. Due to the application of a relatively new product (tissue-glue-coated collagen sponge), after surgery, patients were evaluated by the following assessments: laboratory tests (alkaline phosphatase, blood urea, creatinine, and leukocyte count), neurological examination, and adverse events at postoperative days 1 and 7, and at a 1-month follow-up visit. All patients underwent lumbar X-ray on postoperative day 1 and lumbar MRI at the 1-, 3-, or 6-month follow-up visit (first follow-up visit) according to the patient’s clinical situation.

Evident postoperative internal or external CSF leak was used to determine the patient’s postoperative result.

**RESULTS**

Between March 2015 and October 2018, intraoperative repair of a dural tear was required in 72 consecutive patients during microdiscectomy (n=42) or lumbar spinal decompression (n=30). This represented 3.2% of all elective spinal procedures during the same period. Forty-five were female and 27 were male; their mean age was 41.2 years (range, 22-74 years). In all cases, the initial size of the tear was 10 mm or less. When brisk CSF exit was encountered coming from a tear of the dural sac, the initial treatment involved the use of standard methods (i.e., compression, oxidized cellulose, cottonoid application, gelatin sponge). When
these measures failed, were excessively
time-consuming (persistent CSF leaking
after 2 minutes), or were considered
risky, or when the dural tear enlarged, a
specific method was applied according
to the type of dural tear. The primary
location of the dural tear included the
dorsal surface of the dural sac (n=28 ),
nerve root shoulder (n=24) or nerve
root axilla (n=20). The duration of
surgery ranged from 22 to 95 minutes.

Group 1 consisted of 25 patients
with Type I (mild) dural tear who were
intraoperatively treated with fibrin glue
(n=13) or tissue-glue-coated collagen
sponge (n=12). In this group, postoper-
ative internal or external CSF leak was
not evident during a minimum 1-year
follow-up.

In the 26 patients in Group 2, treat-
ment included both tissue-glue-coated
collagen sponge and fibrin glue. First,
the sponge was applied and kept in
place with a cottonoid until most of the
CSF flow was controlled, and then fib-
rin glue was applied. Internal CSF leak was evident in three cases during the
same follow-up. No external CSF leak was observed.

Strict 24-hour bed rest was indicated
in all patients. No external drain was
used in any case. Laboratory analysis did
not reveal any changes. Clinical or neu-
rological examination revealed initial
improvement in all cases. Postoperative
MRI was performed during the follow-
up period (mean 6 months). Normal
postoperative conditions were found,
with no signs of relapse of disc hernia-
tion, edema, scar tissue, or inflamma-
tion.

Three patients presented with a
small perimuscular CSF collection on
postoperative lumbar MRI. In these
patients, surgical treatment was deemed
to be not necessary. Three other
patients, one from Group 2 and two
from Group 3, presented with subcuta-
aneous wound collection at 1-2 months
postoperatively. After screening by
MRI, these patients underwent re-do
spinal surgery for CSF leak repair.

Our experience supports the
hypothesis that spinal dural tears can be
treated adequately with a particular
technique according to the tear’s
anatomical characteristics. By broaden-
ing our previous experience,11 we cate-
gorized dural tears that may be
encountered in simple spinal proce-
dures into three types, and tailored
treatment based on their complexity.

We used fibrin glue alone for simple
dural tears, i.e., Type I. In a study
designed to evaluate the incidence of
durotomy during elective lumbar spine
surgery and the potential efficacy of fib-
rin glue, prior lumbar surgery was the
only variable that was shown to increase

Figure 5ab. Postoperative pseudomeningocele in a case with Type II dural tear. Axial (a) and sagittal (a) lumbar MRI.
the likelihood of a dural tear. The incidence of persistent CSF leakage was not decreased by the addition of fibrin glue to the dural repair. In all of those cases, an attempt was made at surgery to create a “watertight” dural closure. Closure was performed with 4-0 dural silk sutures. However, since they included all types of dural defects, that study is not comparable to ours.

In some Type I and all Type II dural tears, we used tissue-glue-coated collagen sponge. Although this was initially introduced as a hemostatic agent, like fibrin glue, we use it as a sealant. It is easy to use and provides significant adherence between surfaces to which it has been applied. There have been a few neurosurgical reports on the use of tissue-glue-coated collagen sponge to prevent CSF leakage and to achieve a watertight dural closure in cranial surgery. This fibrin sealant patch is sterile, ready-to-use, and bioabsorbable product that includes two active substances (human plasma-derived fibrinogen and human plasma-derived thrombin) on a collagen sponge of equine origin. The clotting factors form a stable fibrin network that holds the collagen matrix and the wound surface together, thus sealing the lacerated surface. 11 More importantly, the adherence achieved between surfaces is particularly strong. We applied a piece of tissue-glue-coated collagen sponge over the dural tear and used a wet cottonoid for gentle compression of the hemostatic glue-coated collagen sponge to prevent CSF leakage and to achieve a watertight dural closure in cranial surgery. 11 This fibrin sealant patch is sterile, ready-to-use, and bioabsorbable product that includes two active substances (human plasma-derived fibrinogen and human plasma-derived thrombin) on a collagen sponge of equine origin. The clotting factors form a stable fibrin network that holds the collagen matrix and the wound surface together, thus sealing the lacerated surface. 11 More importantly, the adherence achieved between surfaces is particularly strong. We applied a piece of tissue-glue-coated collagen sponge over the dural tear and used a wet cottonoid for gentle compression of the hemostatic agent. In Type II tears, we also applied fibrin glue. The purpose of this study was not to evaluate the tissue-glue-coated collagen sponge as a sealant agent, and in most of our cases, it was used in combination with other techniques or tools. However, in our opinion, it worked well when properly applied.

In more complex cases, i.e., Type III dural tears, we used up to three polypropylene stitches along with a combination of the two previous agents. The decision to suture the dura was made when the laceration was deemed anfractuous and not linear, as in simple Type I and II dural tears. In probably the most detailed study of lumbar spinal dural tears, Takahashi et al. 12 reported that incidental durotomy occurred in four important anatomical spinal areas: the caudal margin of the cranial lamina, the cranial margin of the caudal lamina, the herniated disc level, and the medial aspect of the facet joint adjacent to the insertion of the hypertrophic ligamentum flavum. They reported an overall incidence of 1%. The incidence of dural tear was significantly higher in women (5.6%) than in men (3%). The incidence of dural tear was 2% at disc levels with lumbar disc herniation and with lumbar spinal canal stenosis without spondylolisthesis, 9% with degenerative spondylolisthesis, and almost 20% with juxtafacet cysts; the incidence was significantly higher in levels with degenerative spondylolisthesis or levels with juxtafacet cysts. We were focused on the intrinsic anatomical aspects of the dural tear rather than on the anatomical location. However, the anatomical location of the durotomy may influence its intraoperative management, due to the available space to work, visibility and potential nerve root damage.

In our study, dural tear occurred in 3.2% of all elective, first-time, non-instrumental spinal procedures. Dural tear occurred in 2.5% of primary discectomy and 5.7% of spinal stenosis surgery. These figures are comparable to those in the literature, where reported rates of incidental durotomy are 3.5% for primary discectomy, 6 and from 3.1% to 13% after decompression for stenosis. The incidence of post-discectomy dural tears varies from 1% 6 to 7.1% 1. The rates are higher for revision spine surgery, ranging from 8.1% 6 to 17.4% 1.

In 146 malpractice cases in a study on medicolegal aspects of spine surgery, 2 incidental durotomy was the second-most frequent complication. They suggested that incidental durotomy cannot be considered an entirely benign event. Patients in this study reported assumed complications or neurological deficits secondary to dural tears. Another study 4 on the long-term results of spine surgery complicated by incidental durotomy revealed that, if recognized and repaired intraoperatively, there is no increase in perioperative morbidity and the long-term results of surgery are not compromised. This result was duplicated in another study, where incidental durotomy during first-time lumbar discectomy did not appear to impact long-term outcome in affected patients. 5 The incidence of dural tears was higher in lumbar stenosis than in discectomy, based on national databases. 6, 8 The effect of incidental durotomy on in-hospital morbidity and mortality and health care burdens was more significant in spinal stenosis. 6 However, spinal stenosis is seen more often in older people, while disc herniation is seen in younger populations. Older age, previous surgery and smoking were risk factors for dural tears, but did not negatively affect the 1-year outcome. 9, 10 The characteristics of the dura mater itself are relevant factors for inflicting and sustaining a dural defect.

Other techniques such as blood patch or lumbar external drainage were not used in this study. While we did not need to use them in our cohort, we have to acknowledge that these cases were simple spinal procedures and not complex. Still, three of our patients needed revision surgery for pseudomeningocele formation. These cases were treated with a triple technique (suture, tissue-glue-coated collagen sponge and fibrin glue) and to date have not evidenced internal CSF fistula on imaging studies.

This study has several limitations. Our anatomical classification is based more on the characteristics of the dura mater rupture rather than the anatomical location of the durotomy. The spinal dura mater itself may vary from patient to patient according to the patient’s age, lumbar spine pathology, and other relevant factors, such as extensive steroid treatment. However, this classification may help to determine a step-by-step decision to implement suturing or a combination of sealant agents. This study is not intended to establish definitive guidelines for incidental dural tears. In our opinion, dural tears may vary in complexity and should be treated accordingly. The actual size of the tear and the location of the lesion, which is often a critical factor, can influence the technique for dural repair and the duration of the surgical procedure. However, for small dural tears in the same dural location, as in this cohort, the technique may be chosen according to the anatomical characteristics. Suturing the spinal dura in linear tears with an intact arachnoid may be useless and may unnecessarily prolong the procedure, while potential nerve root damage is also latent. Also, we used a hemostatic agent as a sealant, but our experience was satisfactory.

In summary, we examined a surgical cohort with incidental dural tears during simple lumbar spinal procedures. Depending on the anatomical complexi-
ty of such tears, their intraoperative management can be tailored accordingly. This study in an observational cohort does not allow us to offer guidelines on dural tear management. Further studies will be needed to address these points.

**Authors’ Disclosures**

The authors declare that there are no conflicts of interest.

**REFERENCES**