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Research Article

# Long-Term Results after Extra-Cranial Skull Base Reconstruction - A Cohort Study

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**Abstract**

Indication for post-traumatic skull base reconstruction differs widely among the institutions. The aim of the present study was to assess the long term outcome following skull base reconstruction in a single institution.

**Methods:** 138 of 404 patients undergoing surgical skull base revision after trauma received follow-up examination. Skull base reconstruction was performed because of meningitis (1.4%), rhinoliquorrhoea (5.7%), intracranial air (58.2%) and fracture lines in the CT scan (100%). The surgical approach was transnasal endoscopical in 101 sides and extra-cranial external in 92 sides. Eleven sides were operated with a combined procedure.

**Results:** Intraoperatively Cerebrospinal Fluid (CSF) leakage could be found in 14% of the patients who had no clinical signs of rhinoliquorrhoea preoperatively. Postoperatively, 3.6% and 2.2% of the patients developed rhinoliquorrhoea or meningitis, respectively. Significantly less mucoceles developed following transnasal compared to external approaches (p=0.006).

**Conclusion:** In 14% surgical rhinobase exploration unveils dura laceration with CSF-leakage in patients who demonstrate rhinobase fractures in the CT-scan and have no clinical signs of rhinoliquorrhoea. Transnasal endoscopic surgery should be favored for skull base reconstruction in order to reduce the incidence of mucoceles.

**Keywords:** Skull Base; Traumatic Brain Injury; Basilar Skull Fracture; Cerebrospinal Fluid Rhinorrhea Mucocele; Compliance with Ethical Standards

## Introduction

The present study is about skull base fractures involving the osseous walls of the nasal cavity and the paranasal sinus. In the literature the terms “skull base fracture”, “front basal fracture” or “anterior skull base fracture” are used to describe this condition. To be precise, a skull base fracture does not necessarily involve the walls of the paranasal sinuses and/ or the nasal cavity. The front basal region anatomically consists of the frontal sinus and the median third of the superior orbit rim. The anterior cranial base is formed by the nasoethmoid, the cribriform plate and the planum sphenoidale (Manson 2009 Frontobase: anatomical classification). Fractures of the walls of the sphenoid sinus involving other parts than the planum sphenoidale can have contact to the dura mater of the middle and posterior cranial fossa. Strictly speaking, these fractures cannot be described as anterior cranial base fractures. The expression “rhinobase fracture” was suggested by some authors in order to summarize frontobasal, anterior skull base and sphenoid sinus fractures that are not contained in the latter expressions. Additionally, “rhinobase fracture” expresses the anatomical relationship between the skull base fracture and the paranasal sinuses or nasal cavity [1].

Potential consequences of traumatic disruption of the bony rhinobase, the dura mater and arachnoid membrane can be 1) rhinoliquorrhoea with possible consecutive pneumocephalus and 2) intracranial hemorrhage. Disruption of the natural barrier between the contaminated paranasal sinuses and the brain can lead to ascending bacterial infections that result in e.g. bacterial meningitis in up to 85% of the patients with rhinoliquorrhoea [2, 3]. A meningitis rate of up to 24% is reported in patients with skull base factures without clinical signs of rhinoliquorrhoea and/or intracranial air [4-6]. Bacterial meningitis can appear as early as days after the trauma but also years after the head injury [7].

Surgical reconstruction of the rhinobase is suggested with intent to reduce the early and late onset sequelae of rhinobase fracture related complications.

Indication for rhinobase reconstruction differs widely among different study groups. Several experts recommend rhinobase reconstruction in case of rhinoliquorrhoea [8,9]. Others justify conservative therapy in cases with self-limiting rhinoliquorrhoea [9,10]. A London based group recommended surgery in patients with intracranial air or displacement of the fracture by more than the thickness of the bone [11]. Another center advocates rhinobase exploration without clear clinical and radiological signs of dura laceration [12]. Schoentgen and co-authors summarize that there is no common consensus for diagnosis and treatment of rhinobase fractures, at present [10].

Extra cranial skull base reconstruction entails the risk of acute intra- and perioperative complications and also longtime sequelae. Most frequently reported sequelae are meningitis, recurrent CSF leakage and mucoceles [12]. Each physician´s goal is it to reduce rhinobase fracture related complications while reducing the patient´s




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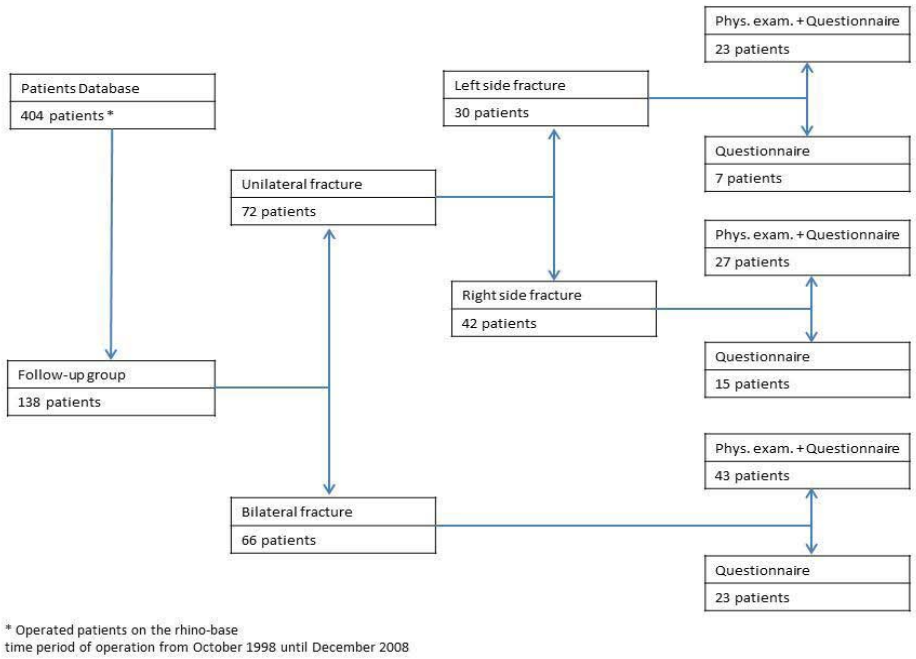


**Figure 1:** Flow chart of the investigated patients; phys. Exam.=physical examination.

**Table 1:** Study´s inclusion and exclusion criteria.

| Inclusion criteria | Exclusion criteria |
|---|---|
| Surgically treated head trauma with skull base fracture that involved the nasal cavity and/ or the paranasal sinuses (rhinobase fracture) | Latrogenic damage to the skull base e.g. as a result of endoscopic sinus surgery |
| Age 18 years or older at follow up | Age under 18 years at follow up |
| Cooperation to answer the questionnaires and perform olfactory testing | |

risk to suffer from surgery related complications or sequelae. The present study does not aim to answer the debate when to perform skull base reconstruction but to investigate the long term outcome after rhinobase reconstruction in a single institution.

## Methods

This single institutional cohort study was approved by the responsible ethic board at Dresden medical school, Technische Universität Dresden/ Germany. Patients gave written consent to participate in the study.

Electronic surgical reports of the Department of Otorhinolaryngology at the TU Dresden Medical School were screened for the German key words indicating skull base reconstruction for a 10 years period (October 1998 to October 2008). Inclusion and exclusion criteria are indicated in Table 1. In the above mentioned period indication for skull base reconstruction was seen when there was either one or multiple of the following conditions: $\beta$-trace or $\beta$- transferrin proven rhinoliquorrhoea, intracranial air, and a visible fracture line in the skull base with contact to the nasal cavity and/or the paranasal sinuses in the Computed Tomography (CT) scans. In general, surgery was performed when the patient was in a stable condition. In case of a communicating wound between the skin and the fractured skull base, rhinobase reconstruction was performed immediately after hospital admission. Additionally, rhinobase reconstruction was performed urgently when there was massive rhinoliquorrhoea and pneumocephalus in order to prevent intracranial hemorrhage due to disruption of intracranial vessels. The surgical approach was set according to the localization of the fracture, additional midfacial injuries or brain injuries and the personal experience of the surgeon. Patients were placed in 30° head and upper part of the body down position (Trendelenburg positioning), jugular veins were compressed bilaterally, Positive End-Expiratory Pressure (PEEP) was increased and intrathecal fluorescein was used in order to visualize the CSF-fistula intraoperatively in indicated cases. Lacerated dura mater and/or the fractured bony skull base were closed mainly with xenografts and fibrin glue or local flaps and fibrin glue. Patients were set on intravenous cephalosporins at the time when rhinobase fracture was diagnosed. Nasal packing was placed until the 2nd or 7th postoperative day.

**Table 2:** Indicated are the numbers of patients and the used approaches separately for the right and the left side. A combination of an external and transnasal endoscopic approach was used in combined approaches.

| Right side | | | Left side | | |
|---|---|---|---|---|---|
| external | transnasal endoscopic | combined | external | transnasal endoscopic | combined |
| 50 | 51 | 7 | 42 | 50 | 4 |

All patients meeting the inclusion criteria were contacted either by mail or by phone to participate in a follow-up examination. Those patients who were not able to return for follow-up were asked to fill and reply the questionnaires. Follow-up examination was performed

**Table 3:** Clinical findings of those 19 patients in whom CSF-leakage was found intraoperatively. Active CSF leakage could be confirmed intraoperatively in 2 out of 8 patients with pre-operative rhinoliquorrhoea (25%), in 7 out of 64 patients with pre-operatively intracranial air (11%) and in 12 out of 46 patients with fracture lines only (26%). FR=frontal recess; SBE=skull base of the ethmoid sinus; SBS=skull base of the sphenoid sinus; SBF=skull base of the frontal sinus.

| Patient´s ID | Pre-operative rhinoliquorrhoea | Intracranial air | Localization of fracture | Localization of intraoperative CSF-leak |
|---|---|---|---|---|
| #82 | No | no | FR, SBE right | FR right |
| #103 | No | yes | SBF,SBE,SBS right | SBF right |
| #34 | No | no | SBF,SBE right | SBF,SBE right |
| #135 | Yes | yes | SBS right | SBS right |
| #109 | No | no | SBF,SBS, FR right | FR right |
| #120 | Yes | no | SBE,SBS left | SBE,SBS left |
| #80 | No | no | SBF, FR left | FR left |
| #134 | No | no | SBE,SBS left | SBS left |
| #51 | No | yes | SBF & SBE right, SBF left | SBF right |
| #14 | no | yes | SBS right SBE & SBS left | SBS right |
| #97 | No | no | SBS right & left | SBS right |
| #131 | No | no | SBF right & left, FR & SBE left | FR & SBE left; SBF right |
| #58 | No | yes | SBE & SBS right, SBF & SBE & SBS left | SBF & SBE & SBS left |
| #50 | No | no | SBE right, SBS left | SBS left |
| #91 | No | no | SBF & SBS right, SBS left | SBF & SBS right |
| #19 | No | no | SBE & SBS right SBF,SBE left | SBS right |
| #83 | No | yes | SBF & SBE right, SBE & SBS left | SBE left |
| #21 | No | yes | SBF & FR & SBE right, SBE left | FR & SBE right |
| #32 | No | no | SBS right & left | SBS right |

**Table 4:** Clinical findings of those two patients who were referred to our hospital because of rhinobase fracture and meningitis. SBE=skull base of the ethmoid sinus; SBF=skull base of the frontal sinus.

| Patient´s ID | Pre-operative rhinoliquorrhoea | Intracranial air | Localization of fracture | Localization of intraoperative CSF-leak |
|---|---|---|---|---|
| #1 | yes | no | SBF left | SBF left |
| #110 | no | no | SBF & SBE right | no |

from November 2011 to August 2012 in the out-patients department of the department of otorhinolaryngology, Dresden medical school.

Medical files of all participants were reviewed for the localization of the rhinobase fracture, presence of rhinoliquorrhoea (positive beta-trace protein or beta-transferrin) or intracranial air, pre-surgical meningitis, surgical conformation of the fracture, surgical approaches, closure techniques and materials. At follow-up, patients were asked for postoperative meningitis and mucocele formation in the frontal, ethmoid and sphenoid sinuses, nasal air flow and olfaction. Medical files were studied for documented postoperative complications. Physical examination included nasal endoscopy to assess chronic rhinosinusitis and mucoceles. A mucocele is an epithelial-lined, mucus-containing sac and is capable of slow expansion and thereby it can lead to bone destruction that can result e.g. in optic nerve compression, displacement of the eye-ball and intracranial expansion. The diagnosis of meningitis was based on compatible clinical signs and one of the following: positive CSF culture or a negative CSF culture in the presence of elevated neutrophil count, elevated protein concentration, and decreased (or less than two-thirds serum glucose concentration to CSF glucose concentration) glucose concentration.

## Patients

414 patients could be identified in our electronic database. 404 patients fulfilled all inclusion and exclusion criteria. 138 patients were available for follow-up examination (Figure 1).

## Results

### General

Twenty-two women and 116 men were available for follow-up. Mean age was 45 years (min. 18 and max. 87 years). Time between rhinobase reconstruction and follow-up examination was at mean 6.5 years (min. 2.2 and max. 13.8 years). None of the patients received revision surgery by a neurosurgeon. Lumbar drainage was not applied in the investigated patients.

**Surgical approaches:** Seventy-two patients were operated unilaterally and 66 patients were operated bilaterally. Summarized 204 sides were operated. Hundred and one sides were operated exclusively via a transnasal endoscopic approach. Ninety-two sides were operated exclusively via an external approach. A combination of an external and transnasal endoscopic approach was used in 11 sides compare (Table 2). The selection of approaches depends on dimensions and localizations of fracture lines. Fracture lines of

**Table 5:** Materials used for rhinobase reconstruction. A combination of two or three materials was applied in several patients.

| Materials | Number |
|---|---|
| TachoSil® | 65 |
| TachoComb® | 33 |
| dura patch | 3 |
| fascia lata | 3 |
| | 3 |
| local flap | 15 |
| pericardial patch | 67 |
| combination of two materials | 39 |
| combination of three materials | 6 |

anterior skull base and medial posterior frontal sinus were covered through endoscopic approach. Complex fracture lines or factures of lateral posterior frontal sinus were treated through external or combined approach.

## Preoperative indication for rhinobase reconstruction

As indicated in the methods section of this manuscript, indication for skull base reconstruction was seen when there was either one or multiple of the above mentioned inclusion conditions.

Eight patients demonstrated rhinoliquorrhoea pre operatively. Sixty-four (58.2%) of 110 patients with available CT-scan reports, exhibited intracranial air in the CT scan, preoperatively. Forty-six (41.8%) of 110 patients had fracture lines without intracranial air in the CT scan. Two patients (#1 and #110) were operated because of meningitis.

**Intraoperative findings:** Focusing on all 138 patients, in 19 patients CSF- leakage was found intraoperatively. Among them are two patients who presented rhinoliquorrhoea preoperatively. Six patients demonstrated intracranial air and twelve patients demonstrated fracture lines without intracranial air in the pre-operative CT-scan. Localization of the fracture lines in those nineteen patients with intraoperatively detected CSF leakage is summarized in Table 3.

Pre-operatively, eight patients demonstrated rhino-liquorrhoea as indicated above. Laceration of the dura with CSF leakage could be confirmed intraoperatively in two of these patients. The remaining six patients showed fractures without intraoperative CSF leakage.

**Meningitis:** Two patients (#1, #110) presented with rhinobase fracture and meningitis. These fractures were closed. Patient #1 received rhinobase exploration in a different hospital where rhinoliquorrhoea was observed intraoperatively. The patient developed meningitis and persisting rhino- liquorrhoea. The patient was transferred to our department where we performed rhinobase reconstruction. Patient #110 had rhinobase reconstruction in another hospital because of rhinobase fracture. One month later the patient was referred to our department with meningitis and encephalitis. Intraoperatively, the fracture lines were explored but no active CSF leakage was found. The fracture lines were covered by TachoSil® compare (Table 4).

**Reconstruction materials:** Seven different materials or a combination of these were used for the reconstruction of rhinobase compare (Table 5,6). Most frequently TachoSil® and (bovine or porcine) pericardial patch were applied. The rhinobase was reconstructed with a combination of two materials in 39 patients. Three different materials were applied in 6 patients.

## Postoperative complications

**Rhinoliquorrhoea:** Five patients (#90, #46, #19, #134, #133) developed rhinoliquorrhoea postoperatively. Indication for rhinobase reconstruction in those 5 patients was set as following: One patient demonstrated rhinoliquorrhoea pre-operatively. In two patients CSF-leakage was found intraoperatively. The remaining two patients had fracture lines without intraoperative CSF- leakage. None of these five patients had intracranial air in the preoperative CT scan. All patients received revision surgery where active CSF-leakage could be visualized. Neither lumbar drainages nor neurosurgical transcranial approaches were needed to successfully seal these CSF-fistulas.

## Meningitis following surgery in our hospital

Three patients (#90, #123, #133) developed meningitis following surgery in our department. One of these patients (#90) developed meningitis 6 years after closed rhinobase fracture and rhinobase reconstruction. In the initial surgery there was freely exposed dura mater without bony coverage and no signs of CSF-leakage. When the patient presented with meningitis Fluorescein was applied intrathecally. Intraoperative exploration of the rhinobase did not reveal rhinoliquorrhoea. The previous fracture area was again covered with TachoSil®. Under intravenous antibiotics the patient recovered. The second patient (#123) presented with meningitis 3 weeks after closed rhinobase reconstruction following massive rhinobase fracture with discharge of brain tissue into the nasal cavity. The patient received revision surgery for rhinobase exploration but no signs of CSF- leakage could be found. The third patient (#133) was initially operated because of a rhinobase fracture in the frontal sinus and in the sphenoid sinus. There were neither preoperative nor intraoperative signs of CSF-leakage. The initial CT scan showed no intracranial air. At the 5th post-operative day rhinoliquorrhoea was

**Table 6:** Clinical findings of those 13 patients who developed a mucocele. The localization of the mucocele could not be revealed (n.i.) in three patients.

| Patient´s ID | Localization of mucocele | Approach for rhinobase reconstruction |
|---|---|---|
| #7 | Bilateral frontal sinus | External bilateral |
| #20 | Bilateral sphenoid sinus | Endonasal Bilateral |
| #29 | Right frontal sinus | External bilateral |
| #35 | Right frontal sinus | External right |
| #43 | Right frontal sinus | External right |
| #46 | Left frontal sinus and ethmoid | External left |
| #69 | Left sphenoid sinus | External bilateral |
| #62 | n.i. | Endonasal right, external left |
| #1 | n.i. | External left |
| #77 | Left frontal sinus | External left, endonasal right |
| #101 | Right frontal sinus | External bilateral |
| #124 | Left frontal sinus | External left |
| #133 | n.i. | External bilateral |

observed and the patient received revision surgery. The patient was admitted to the hospital 14 days after revision surgery with meningitis. Again, rhinobase was explored. Purulent secretion was found in the frontal sinus. There was no sign of rhinoliquorrhoea.

### Development of mucoceles

Thirteen patients developed a mucocele of the paranasal sinuses within the follow up period. Mucoceles developed in 2 out of 101 (2%) transnasal endoscopically treated sides while mucoceles were observed in 11 out of 92 (12%) sides which were operated using an external approach. The mucocele could not be assigned to the used approach in two additional patients. Qui-square-test revealed significant less mucoceles in the endoscopically treated patients (qui-square-value 7.63; df=1; p=0.006).

**In detail:** One patient developed a mucocele in the left and the right sphenoid sinus following a bilateral endoscopic rhinobase reconstruction. 10 patients developed unilateral mucoceles on the side that was operated via an external approach. Patient (#133) received a bilateral external approach but could not indicate the side of the mucocele that was operated in different hospital. Patient (#1) who received rhinobase reconstruction via an external approach on the left side previously, indicated surgery for a mucocele in a different hospital without remembering the side. A second patient (#62) who was operated via a transnasal approach on the right side and via an external approach on the left side indicated surgery for a mucocele elsewhere but could not remember the side.

## Discussion

The present study sheds new light on the outcome of rhinobase reconstruction in patients who were treated surgically because of rhinobase fractures. Among the studied population 1.4%, 5.7%, 58.2% and 100% of the patients were operated because of meningitis, rhinoliquorrhoea, intracranial air and fracture lines in the CT scans, respectively. Due to the diversity in the management of skull base fractures, the majority of our patients would not have been operated in other centers [9]. However, Elies justified rhinobase exploration in cases of CT-morphological fractures [12]. The author indicated that in 25% of his patients a CSF leakage was found intraoperatively although there was no clinical rhinoliquorrhoea preoperatively. Nowadays, it is widely believed that CSF leakages should be closed surgically to avoid ascending infections like meningitis although no study specifically demonstrated a beneficial effect, yet [2,7,8,10]. Eljamel reports a rate of meningitis in cases of non-surgically treated rhinoliquorrhoea of 6.6% and 7.6% within one week and one year, respectively [13]. Other study groups report much higher rates of meningitis of 29% or even 85% within 5 years after the trauma [2,3]. Bernal-Sprekelsen and Co-authors state that this high incidence of meningitis is not acceptable and favor early endoscopic closure of the fistula. Preoperative clinical manifest rhinoliquorrhoea was found in 8 (5.7%) of our patients. Interestingly, in only 2 out of these 8 patients active CSF leakage could be visualized while exploring the rhinobase in those patients. On the other hand focusing on the patients who preoperatively did not demonstrate rhinoliquorrhoea, our data suggest that 19 of 130 patients (14.6%) had active CSF leakage intraoperatively. These facts illustrate the dilemma. On one side we could visualize the CSF leakage intraoperatively only in 25% of the patients who presented with rhinoliquorrhoea preoperatively. On the other side we found active CSF leakage intraoperatively in 14.6% of the patients who did not present rhinoliquorrhoea preoperatively. There are several explanations for these conditions. An initial fistula can be closed by e.g. a clot, a brain herniation or an early scar formation that make it impossible to visualize the fistula intraoperatively. On the other hand a fistula might be present but result in a non-clinically detectable rhinoliquorrhoea or the fistula opens when the intracranial pressure decreases while the patient is operated in general anesthesia [14,15]. One could assume that in almost 60% of the patients there could be a skull base fistula when extrapolating our finding that the rate of CSF leakage is four times higher than it can be visualized intraoperatively (CSF leakage could be visualized in 25% of the patients with preoperatively manifest rhinoliquorrhoea and CSF leakage could be found intraoperatively in 14.6% of the patients without preoperatively manifest rhinoliquorrhoea). That would give good reason for rhinobase reconstruction in patients with CT-morphologic skull base fractures even in cases without apparent CSF leakage. Another approach could be to identify those patients who are on high risk to present rhinoliquorrhoea intraoperatively.

In the present study the rate of surgically detected active CSF leakage was 50%, 25%, 11% and 26% in those with meningitis, pre-operative rhinoliquorrhoea, intracranial air and fracture lines, respectively. Table 3 illustrates the diverse localizations of the CSF leakages at the rhinobase. It appears that our pre-operative indication for surgery as well as the localization of the fracture lines cannot predict the appearance of intraoperative CSF leakage. However, the motivation for surgery in our studied patients was to reduce their risk to develop meningitis. The above mentioned incidence of meningitis (6.6 to 85%) was calculated in patients with clinically apparent rhinoliquorrhoea [2,3,13]. It is not clear whether patients who have no preoperative rhinoliquorrhoea but present an intraoperative CSF leakage have the same risk to develop meningitis like patients with preoperative clinically apparent rhinoliquorrhoea. According to a study from the 1950´s none of 50 patients with skull base facture without rhinoliquorrhoea developed meningitis within 5 years (range 1.5 to 12 years) [5]. That would mean that 94% of our studied population received over-treatment. Other studies reported an accumulative risk of meningitis of 85% after 10 years with a mortality rate of 25 - 50% [3]. In harsh contrast to later studies, the same study indicates that none of the 27 patients who received conservative treatment of rhinoliquorrhoea developed meningitis during the above mentioned follow-up period. Another study from the pre-World War II era indicated 6 cases (24%) of meningitis following skull base fracture without rhinoliquorrhoea and x-ray morphological intracranial air [6]. Four of these 6 patients died as a result of intracranial infections. Despite our efforts to prevent meningitis, three patients developed meningitis (2.2%) following rhinobase reconstruction in our department. Interestingly, none of the 3 patients presented active CSF leakage prior or during revision surgery. Only in one patient a focus with purulent secretion was found close to the rhinobase that could explain ascending meningitis. The mechanistic concept of direct contact of pus with the dura mater that results in bacterial meningitis is certainly just one possible explanation. Lung infections and endocarditis are predisposing factors for the development of bacterial meningitis which suggests a hematogenous spread of the germs [18,19].

The rate of 2.2% of post-operative meningitis in the present study is in line with previous studies from Bernal-Sprekelsen et al. and from Rocchi G et al. which report rates of 2.6% and 5.6% [20,21]. Bernal-Sprekelsen and colleagues studied rates of post-operative meningitis following transnasal endoscopic closure of dura fistula in 39 patients with proven rhinoliquorrhoea or meningitis. The authors indicate a post-operative meningitis rate of 2.6% within a follow-up period of 65 month (min. 22 max. 120 month). At first sight their meningitis rate appears comparably low like in the present study (2.2% among 138 patients). But, when looking at our ten patients with pre-operative CSF-leakage or meningitis, who match with the studied patients of Bernal-Sprekelsen et al., we had not a single case of meningitis during the follow-up interval. None of the three patients who developed meningitis in the present study strictly fit the indicated inclusion criteria of Bernal-Sprekelsen´s and Co-authors´ study. Additionally, the authors did not follow-up those patients with rhinobase fracture without CSF-leakage. Doing though, we would have missed our three patients who developed meningitis.

Every medical intervention implicates the risk of side effects. Specifically, rhinobase reconstruction put the patient on risk to suffer surgery-related complications including bleeding, wound infections or endonasal scaring. The present study focused on mucoceles - one possible sequel. In the present study 13 patients developed mucoceles. At least 2 patients (maximum 4 patients) presented a bilateral mucocele. In other words, a mucocele occurred in 7.4% of the operated sides or in 9.4% of the patients. Causes for mucocele formation in the paranasal sinuses are divers. Besides sporadic development of mucoceles, non-iatrogenic risk factors are chronic rhinosinusitis and traumata e.g. fracture of the paranasal sinuses [22-24]. Interestingly, no single mucocele developed on the non-fractured side in those 72 cases with unilateral rhinobase fracture. Chobillon and Jankowki estimate the risk for mucocele development in non-surgically treated chronic rhinosinusitis at 0.6% while the figure increases to 5.3% within 6 years in transnasal endoscopically treated patients [24]. The rate of mucoceles in the present study was twice as high as in Chobillon and Jankowki´s study. This figure might be explained by the high rate of external approaches in the present study. Significantly (p=0.006) less mucoceles developed following endoscopic surgery compared with external approaches. In our patients, mucoceles developed in 2 out of 101 (2%) transnasal endoscopically treated sides while mucoceles were observed in 11 out of 92 (12%) sides which were operated using an external approach. That is a surprisingly low incidence in the endoscopically treated patients; especially considering studies indicating that mucoceles arise significantly earlier following endoscopic transnasal surgery compared to external approaches to the sinuses [25,26]. On one hand, rhinobase reconstruction was performed in non-inflamed sinuses in the present study. That fact might underline the role of chronic inflammation in the development of mucoceles [27]. On the other hand, 12% of mucoceles following external approaches illustrate a comparable high incidence. Elies reports mucocele formation in 22.4% of patients who received external approaches for rhinobase reconstruction [12]. That high incidence of mucoceles following external approaches should be avoided by favoring transnasal endoscopic surgery. However, the lateral recess of the frontal sinus is not assessable transnasally with rigid endoscopes that makes it impossible to close skull base defects in that location. Transorbital endoscopic surgery is an alternative approaches that might be less invasive for the lateral recess of the frontal sinus [28]. Nevertheless, future studies have to prove whether this approach might be associated with less long-term sequelae than extensive external approaches.

## Conclusion

In 14% surgical rhinobase exploration unveils dura laceration with CSF-leakage in patients who demonstrate rhinobase fractures in the CT-scan and have no clinical signs of rhinoliquorrhoea. Although it is nowadays widely believed that in patients with rhinoliquorrhoea skull base reconstruction reduces the risk for post-operative meningitis, a prospective study is needed that systematically investigates that issue. Every physician who recommends skull base reconstruction in patients with rhinoliquorrhoea should consider rhinobase exploration even in patients with rhinobase fractures without rhinoliquorrhoea because a significant number of patients with dura laceration can just be identified surgically. Furthermore, transnasal endoscopic surgery should be favored for skull base reconstruction in order to reduce the incidence of mucoceles following external approaches.

All patients who participated in the study gave informed consent.

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