Spontaneous sphenoid sinus cerebrospinal fluid leak and meningoencephalocele – are they due to patent Sternberg's canal?

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Abstract

Sternberg's canal is a congenital bony defect in the lateral wall of the sphenoid sinus. If it persists to adulthood, it may become a source of spontaneous cerebrospinal fluid leak (CSF) and meningoencephalocele. The aim of the study was to describe the authors' experience and review articles related to spontaneous sphenoid sinus CSF leaks and Sternberg's canal. We analysed patients managed surgicallly due to sphenoid sinus CSF leak and performed a PubMed database search. Two female patients with spontaneous CSF leak of sphenoid origin were found. Both patients underwent surgery with the endoscopic endonasal approach, and the defect was closed using the multi-layer technique. Twelve articles related to CSF leaks of sphenoid origin (due to Sternberg's canal) were found in the PubMed database. Lines of lesser resistance within sphenoid bone may underlie CSF leak pathology together with intracranial hypertension. The endoscopic transnasal approach to the sphenoid sinus is an excellent alternative to standard transcranial procedures.

Key words: *Sternberg's canal, spontaneous cerebrospinal fluid leak, endoscopic endonasal approach, multilayer dural repair, sphenoid sinus meningoencephalocele.*

Introduction

The term "spontaneous cerebrospinal fluid leak" has been applied to patients without previous trauma, surgery, malformation, tumor or radiation therapy [1, 2]. In comparison with other localizations, sphenoid sinus is a rare source of cerebrospinal fluid (CSF) leak [3]. However, spontaneous CSF leak may be more common in this localization than secondary CSF leak [2, 3].

Complicated ontogenesis of sphenoid bone may promote pathological bony defects within the sphenoid sinus wall. During embryological development, independent cartilaginous precursors are formed separately to become, after the ossification period, particular parts of the sphenoid bone: presphenoid (anterior sphenoid bone), basisphenoid (posterior sphenoid bone), orbitosphenoid (lesser wings), and alisphenoid (greater wings, lateral parts of the pterygoid process). Only the medial plate of the pterygoid process is built up by membranous ossification (Figure 1). The fusion of central sphenoid bone parts and lateral sphenoid bone parts separately takes place before birth. Of major importance is the fusion of central with lateral parts that occurs after birth. Only a weak cartilaginous connection between central and lateral parts has been found in neonates' bones. Thus, the fusion plane creates a line of lesser resistance within the sphenoid bone. Ossification of this cartilaginous connection starts anteriorly and progresses posteriorly [4–6]. Before final fusion, a small canal connecting the middle cranial fossa with the nasopharynx is created, called the lateral craniopha-

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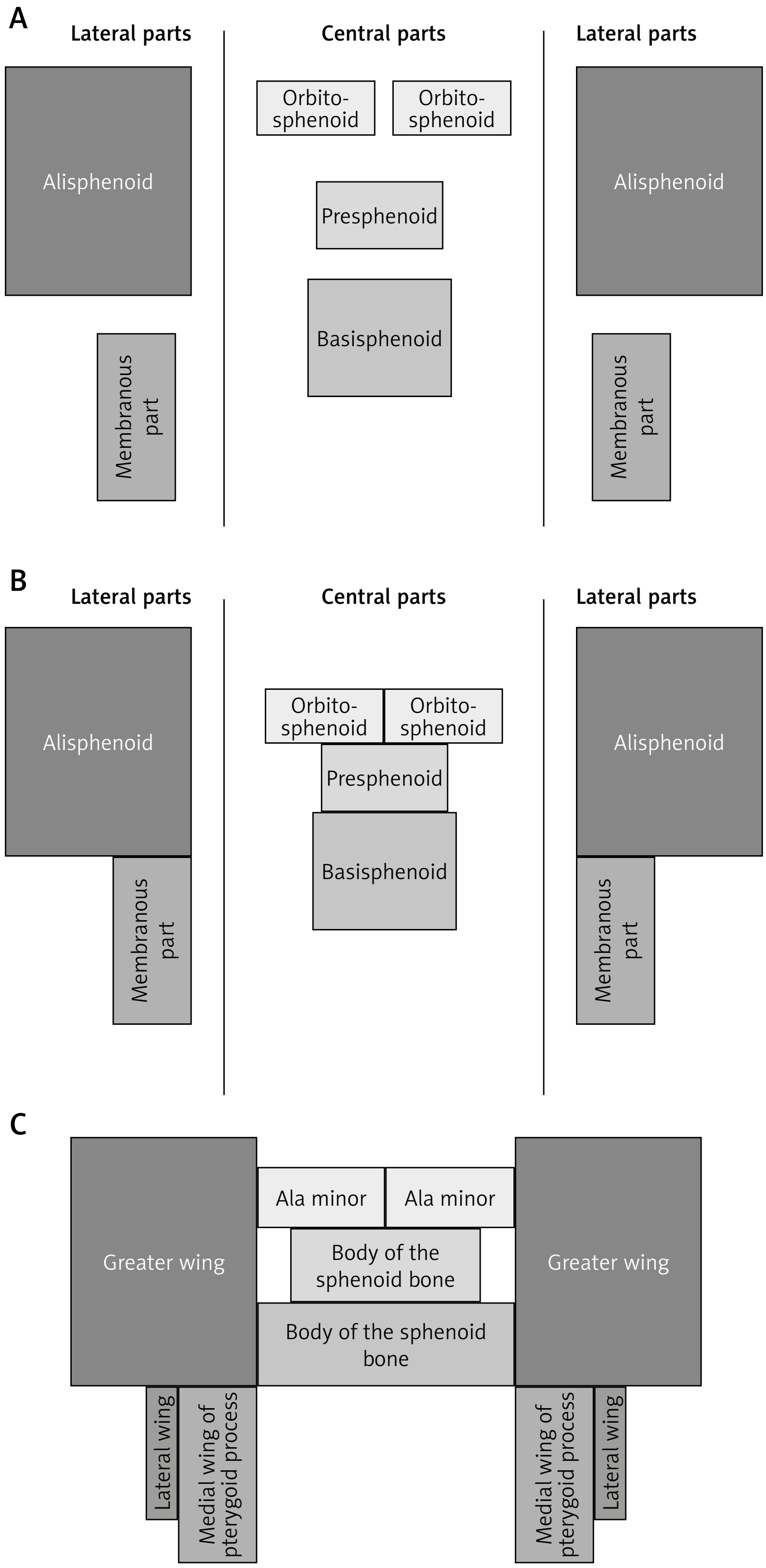

Figure 1. Sphenoid bone ontogenesis: **A**, **B** – prenatal period, **C** – postnatal period

ryngeal canal. By definition, the lateral craniopharyngeal canal starts intracranially between the sphenoid bone body and the posterior roof of the lesser wing and goes downwards on the side of the sphenoid bone body into the nasopharynx, where it ends at the level of the vaginal process (near the vomerovaginal canal). Thereby, it goes exactly at the fusion plane between the central part and the lateral parts.

Presence of the lateral craniopharyngeal canal was discovered for the first time by Cruveilhier in 1877, and 11 years later by Sternberg in 1888 [7, 8]. Over the last decade, most authors have used the term Sternberg's canal. Sternberg described constant presence of the canal in the skulls of 3–4 year old children. The ossification process continues up to the age of 10, until the canal is closed. Under unknown circumstances, Sternberg's canal may persist patent until adulthood (Photo 1). When the sphenoid sinus develops and reaches the fusion plane, Sternberg's canal may create a connection between the middle fossa and the sphenoid sinus, and thus become a potential source of CSF leak, meningoencephalocele or meningitis [9].

The aim of this study is to describe the authors' experience with spontaneous sphenoid sinus CSF leaks and meningoencephaloceles, and to review articles related to Sternberg's canal in the PubMed database.

Case reports

Patients with CSF leak due to sphenoid sinus pathology were identified in a retrospective review of medical records between 2000 and 2012. The study was approved by the Ethics Committee at the Medical University of Warsaw. All patients with a history of trauma, previous sinus or skull base surgery or radiotherapy were excluded. Clinical data of presenting symptoms, gender, age, and body mass index (BMI) were reviewed. The exact anatomic localization of the bony defect within the sphenoid sinus was obtained from available preoperative imaging studies and compared to those from operative reports. Histological examination data were reviewed, and the surgical approach, skull base reconstruction technique and final operative result were noted. During the follow-up period, patients were evaluated in endoscopic examination.

The authors searched the PubMed database with the phrases Sternberg's canal, lateral craniopharyngeal canal, sphenoid sinus encephalocele, and sphenoid sinus spontaneous CSF leak in an attempt to find and critically review all the described cases of sphenoid sinus spontaneous CSF leak due to persistent Sternberg's canal.

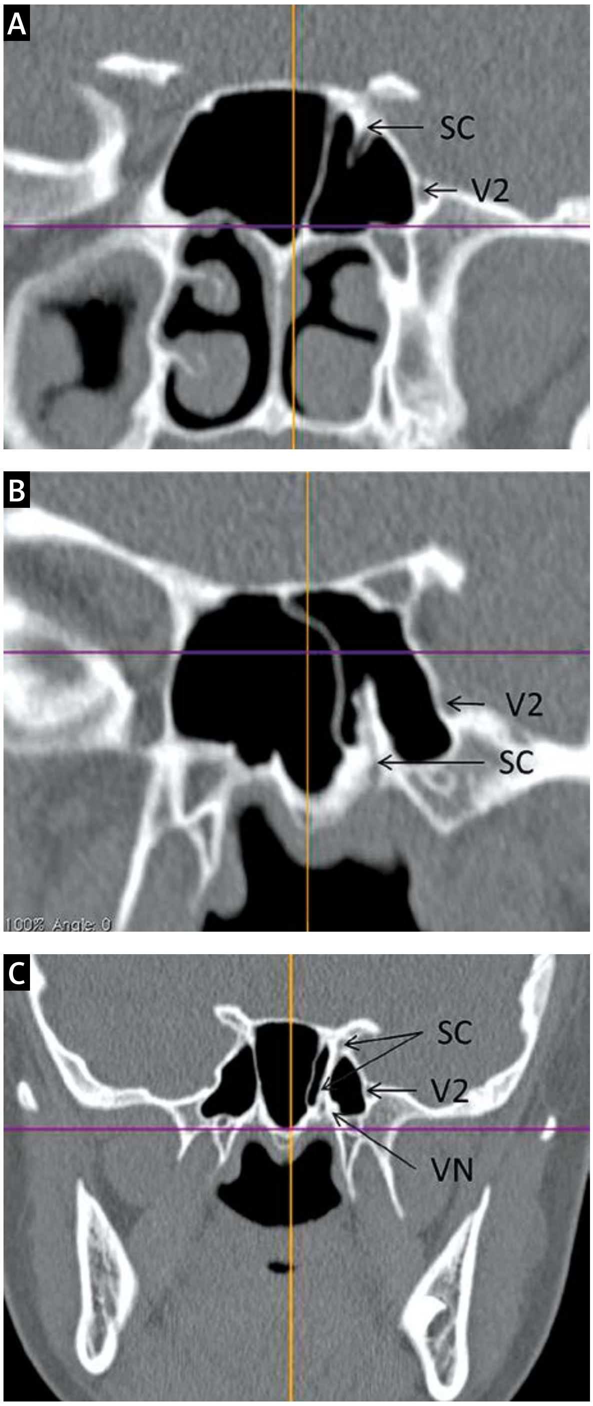

Photo 1 A–C. A 13-year-old patient with an accidentally found Sternberg's canal (SC)

V2 – Second branch of trigeminal nerve, VN – Vidian nerve.

Two patients with spontaneous CSF leak from the sphenoid sinus were identified in our records.

Case 1

A 66-year-old female patient, obese, suffered from long-lasting intermittent left-sided watery nasal discharge. There were no clinical signs of elevated intracranial pressure. The ENT examination revealed left-sided rhinorrhea. This was confirmed by biochemical tests of the albumin/glucose levels. Computed tomography (CT) scans were performed in coronal sections (Photo 2). They disclosed a round-shaped pathological lesion partially occupying the left sphenoid sinus. The lesion was connected with the lateral wall of the sinus. A coronal T1-weighted magnetic resonance imaging (MRI) of the brain clearly depicted cephalocele herniation through the floor of the middle cranial fossa into the left sphenoid sinus. Additionally, MRI revealed the presence of arachnoid cyst in the parietal region (Photo 3). There was no enlargement in ventricular size, nor an empty sella. The patient was operated on using the endoscopic approach, i.e. the transethmoidal-sphenoidal approach (TESA). The site of origin was confirmed on the lateral wall of the left sphenoid sinus. The lesion was cauterized and resected. The tissue sample was sent for histological examination. All of the mucosa and periosteum of the sphenoid sinus was removed carefully to denude the bone. We plugged the dehiscence in the middle fossa with abdominal fat before applying fascia lata and a mucoperiosteal free flap with the overly technique. Lumbar drainage was not used at the time of surgery. A histological examination confirmed the presence of brain tissue within the sample. The patient was followed up for 3 years without any suspicion of recurrence.

Photo 2. Case 1. CT scan with round shaped lesion situated within anterior portion of left sphenoid sinus

Case 2

A 72-year-old female patient, obese, suffered from long-lasting right-sided watery nasal discharge. There were no clinical signs of elevated intracranial pressure. The ENT examination revealed right-sided rhinorrhea, confirmed by biochemical tests of the albumin/glucose levels. High resolution coronal CT scans disclosed a highly pneumatized lateral recess of the sphenoid sinus that extended laterally to the foramen rotundum into the greater wings of the sphenoid bone (Photo 4). The lack of bone between the middle cranial fossa and the roof of the lateral recess was evident with a pathological mass protruding

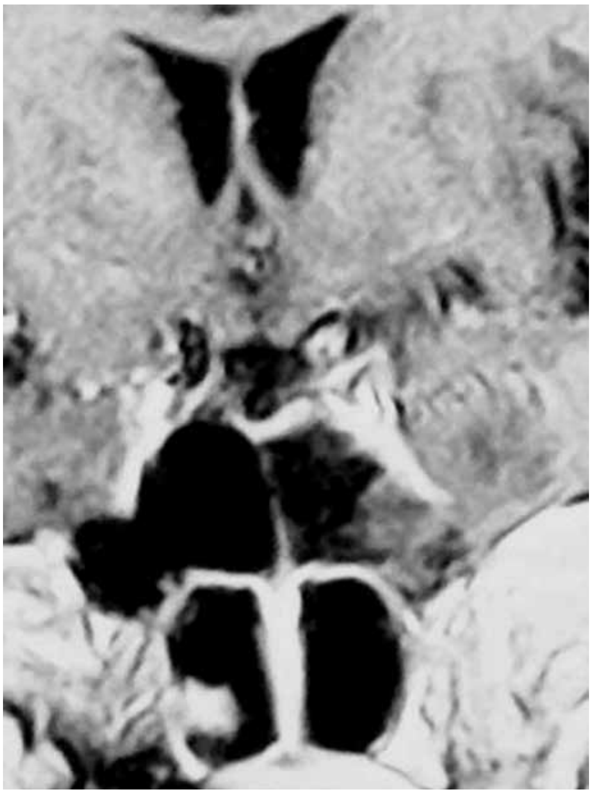

Photo 3. Case 1. Coronal T1 weighted MRI of the brain showing a pathological tissue herniation through the floor of the middle cranial fossa into the left sphenoid sinus

Photo 4. Case 2. HRCT showing highly pneumatized lateral recess, lack of bony border of the middle cranial fossa, pathological mass protruding into right sphenoid sinus

into the left sphenoid sinus. A coronal T2-weighted MRI of the brain depicted polycystic tissue herniation through the floor of the middle cranial fossa into the left lateral recess of the sphenoid sinus (Photo 5 A). There was a partially empty sella on sagittal T2 MRI (Photo 5 B). Due to far lateral extension of the sphenoid sinus, the endoscopic transethmoidal-sphenoidal-pterygoidal approach (TESPA) was chosen as the surgical procedure. We began with a wide maxillary antrostomy followed by complete sphenoethmoidectomy performed in a standard manner. After that, an attempt to expose the posterior wall of the maxillary sinus was performed. The sphenopalatine artery was exposed and coagulated. The posterior wall of the maxillary sinus was then removed and the pterygopalatine fossa was entered. We carefully identified and coagulated the branches of the maxillary artery. The deeper neural structures of the pterygopalatine fossa were identified and transposed laterally and inferiorly to expose the base of the pterygoid process, which was then drilled away. We then entered the lateral recess of the sphenoid sinus. The V2 was localized and preserved. After having identified the leak, the encephalocele was cauterized and resected. Mucosa and periosteum around the defect were removed to denude the bone. A multilayer closure of the defect was performed. The first layer of abdominal fat followed by fascia lata was placed intracranially (underlay technique). The second layer of fat tissue and the last one, mucoperiosteum from the middle turbinate, were put into the sphenoid sinus using the overlay technique, and additionally fixed with fibrin glue. Lumbar drainage was not used at the time of surgery. The follow-up lasted 1 year with

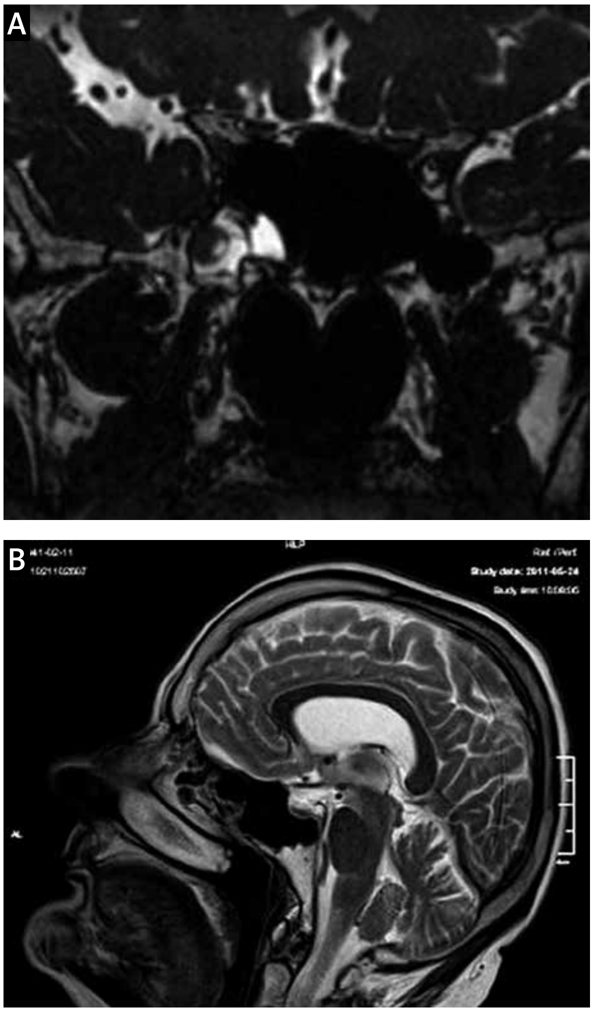

Photo 5. Case 2. **A** – Coronal T2 MRI revealing polycystic tissue herniation through floor of middle cranial fossa into highly pneumatized lateral recess of sphenoid sinus. **B** – Sagittal T2 MRI revealing partially empty sella turcica

endoscopic examination of the nasal cavity being performed every 3 months. There were no signs of recurrence.

The authors found twelve articles devoted to Sternberg's canal (lateral craniopharyngeal canal) in the PubMed database. Eleven of them were clinical case series with 43 cases described overall (Table I). The last one was devoted to the use of radiological investigations to estimate the presence of Sternberg's canal.

Discussion

Nasal CSF leaks may arise from pathology of the anterior, middle and posterior cranial fossae. Their

Table I. Sternberg's canal case series from PubMed database

No.	Author year	No. of cases	Gender	Age [years]	BMI [kg/m²]	Symptoms	Radiological findings	Origin site of the bony defect. Authors' description	Origin site of the bony defect based on CT/MRI	Origin site of the defect in relation to V2–VN line	Extensive lateral recess
1	Bernstein 1997 [15]	2	F siblings	40 41	Obese	CSF leak Meningitis: 1 pt – twice Headache: 1 pt	Cephalocele	Posterolateral region of ss	Within lateral recess of ss – 1 pt Parasellar bony defect – 1 pt	Medially to V2	Yes
2	Schick 2000 [9]	1	F	29		CSF leak	Cephalocele	Parasellar bony defect, posterolateral region of ss	Parasellar, posteriorly to anterior clinoid process	Medially to V2	Yes
3	Blaivie 2006 [17]	1	F	73	Obese	CSF leak meningitis	Cephalocele 2 chronic subdural hematomas Partially empty sella	Posterosuperior wall of ss, paramedial at the roof of ss	Parasellar region; the pathological lesion in direct contact with the partially empty sella	Medially to V2	No (small recess)
4	Castelnuovo 2007 [18]	15	F – 9 M – 6	Mean 60.3; 34–75	Mean 30	CSF leak: 15 pt Meningitis: 3 pt Headache: 2 pt	Cephalocele	Within lateral recess of ss	Insufficient data	Insufficient data Most cases laterally to V2	Yes
5	Tomazic 2009 [20]	5	F – 4 M – 1	Mean 51.2 42–62	Mean 31.3	CSF leak: 5 pt Headache: 2 pt	Cephalocele	Within lateral recess of ss	Lateral recess	Laterally to V2	Yes
6	Tabaee 2010 [21]	13	F – 8 M – 5	Mean 57.1 36–78	No data	CSF leak: 11 pt Meningitis: 2 pt Headache: 10 pt	Cephalocele	Within lateral wall of ss	Within lateral wall of ss	Medially to V2	No data
7	Bendersky 2011 [23]	2	F	43 73	No data	CSF leak: 2 pt Meningitis and headache: 1 pt	Cephalocele	Within lateral recess of ss	Insufficient data	Medially to V2	Yes
8	Izquierdo 2012 [25]	1	M	53	No data	CSF leak Benign intracranial hypertension	Cephalocele	Lateral wall of ss	Lateral wall of ss	Medially to V2	Yes – small within the base of pp
9	Samadian 2012 [22]	1	F	23	No data	CSF leak	Cephalocele	Lateral recess of ss	Lateral recess of ss The recess roof	Laterally to V2	Yes
10	Maselli 2012 [24]	1	F	45	No data	CSF leak Positional headache	Cephalocele	Parasellar bony defect	Lateral wall of ss	Medially to V2	Yes – small one
11	Sanjari 2013 [26]	1	F	45	No data	CSF leak Headache	Cephalocele Empty sella	Lateral side of sphenoid cavity – insufficient data	Insufficient data	Insufficient data	Insufficient data

ss – Sphenoid sinus, pp – pterygoid process, pt – patient, V2 – second branch of trigeminal nerve (maxillary nerve), VN – Vidian nerve.

origin is either spontaneous or secondary due to different medical events, such as trauma or surgery. There is agreement among physicians, based on clinical data, that the most common site of CSF leak is the floor of the anterior cranial fossa, which communicates either with the sinuses (i.e. ethmoidal, frontal) or directly with the nasal cavity [3]. Most cases are of traumatic origin [3, 10]. Estimates of the spontaneous origin of CSF rhinorrhea range from 6% to 23% among all causes of CSF leaks [10–14]. During the last decade, more attention has been drawn to the sphenoid sinus as a potential source of spontaneous CSF leak and middle cranial fossa cephalocele. Recent data suggest that spontaneous sphenoid sinus leaks are even more frequent than secondary ones. Shetty *et al.* retrospectively reviewed 145 cases of CSF fistula (both spontaneous and secondary) and estimated that 10% of them involved the sphenoid sinus, and 7% of all cases were spontaneous leaks from the sphenoid sinus [3]. Schuknecht *et al.* described among 27 cases of spontaneous CSF rhinorrhea 46.4% cases of sphenoid origin [2]. Thereby, we hypothesize that there must be special anatomical or physiological conditions predisposing the sphenoid sinus to become a source of spontaneous CSF leak. When discussing these conditions, we should also take into account either congenital or acquired nature of that pathology. In accordance with the literature, the possible sites of sphenoidal osseodural defects are the upper roof of the lateral recess of the sphenoid sinus, the persistent Sternberg's canal (lateral craniopharyngeal canal), parasellar region, and sphenoid roof [2, 3, 9, 15–26]. In anatomic investigations, bony dehiscences were also described alongside the internal carotid artery groove as a result of pulsatile forces pushing against the lateral wall of the sphenoid sinus [27].

Sternberg's canal (lateral craniopharyngeal canal) has been recently proposed by many authors as an underlying factor related to sphenoid sinus spontaneous CSF leaks. There are two main anatomical requirements for the lateral craniopharyngeal canal to be considered a potential source of CSF leak. The first requirement involves ossification disturbances within the fusion planes of the sphenoid bone which allow the lateral craniopharyngeal canal to persist patent until adulthood. The second one is the presence of a sufficiently pneumatized sphenoid sinus. The formation of the sphenoid sinus continues until the age of 20. There is common agreement that the bone is reabsorbed under the influence of mucosa, and the process should stop at the edge of the sphenoid body, leaving a sheet of bone covering the sinus. When the pneumatization process reaches Sternberg's canal, the connection between the middle cranial fossa and the sphenoid sinus is created. Estimates on the incidence of persisting patent lateral craniopharyngeal canal range widely from 0.42% to 6.1% in anatomical cadaver studies of the adult population [8, 27–29]. Remnants of this canal, too small to allow communication between the sinus and intracranial cavity, were seen in 18.1–28.4% of half sphenoid bones [27, 29]. The newest data, based on high-resolution CT scans, do not confirm these numbers. Baranano *et al.* investigated 1000 high-resolution CT scans of sphenoid bones in an attempt to assess bony defects possibly representing Stenberg's canal [19]. They found only one defect consistent with the anatomical description of the canal's localization, which they claim should be located medially to V2 within the lateral wall of the sphenoid sinus. Moreover, the identified canal was smaller than the anatomic demonstration of the true canal.

The PubMed search related to Sternberg's canal revealed twelve articles (Table I). Bernstein *et al.* did not use the term Sternberg's canal, but he strongly suggests the congenital origin of the two described cases of cranial base defects; thus we decided to include the paper in the analysis [15]. Eleven articles were clinical case series, which describe a total of 43 patients with spontaneous sphenoid sinus CSF leak due to a patent lateral craniopharyngeal canal.

When analyzing the bony dehiscences referred to as Sternberg's canal, we noticed heterogeneous descriptions of them. The site of origin was depicted by different authors with terms such as: posterolateral region of the sphenoid sinus, posterosuperior wall of the sphenoid sinus, parasellar region, within the lateral recess, within the lateral wall and on the lateral side of the sphenoid cavity. According to different types of sphenoid pneumatization, all of these terms seem to be imprecise. Moreover, by definition Sternberg's canal starts intracranially between the sphenoid bone body and the posterior roof of the lesser wing and goes downwards on the side of the sphenoid body into the nasopharynx, where it ends at the level of the vaginal process (near the vomerovaginal canal). According to this anatomical description, Baranano *et al.* claim that the canal has to be located medially to the superior orbital fissure, thus medially to the foramen rotundum and V2 [19]. Relying on this statement, 22 of the reviewed cases showed the defect localized medially to V2 (19 cases described on the lateral wall of the sinus; 3 cases in the parasellar region). On the other hand, Tomazic and Stammberger define the defect related to Sternberg's canal laterally to V2 (5 cases) [20]. Castelnuovo *et al.* also describe most of their cases laterally to V2 (in a study group of 15 patients) [18].

The question arises whether both localizations have a homogeneous origin. There is a lot of controversy about whether the lesions occurring laterally and medially to V2 are of the same origin and about the relation between the lateral recess leaks and Stemberg's canal. Extensive lateral pneumatization of the sphenoid sinus across the line connecting V2 and the Vidian nerve into the pterygoid process and/or greater wing creates the lateral recess of the sphenoid sinus. This anatomical variation of the sinus may promote thinning of the skull base between the middle cranial fossa and sinus cavity.

In 1977, Kaufman *et al.* proposed a theory of the acquired nature of nontraumatic, normal pressure CSF leaks [30]. The authors pointed out that the coincidence of anatomical and physiological factors has to be taken into account to explain the pathogenesis of this kind of leak. As the authors suggest, pneumatization of the sinuses along the skull base in conjunction with pulsatile forces and intermittently increased CSF pressure may erode the thin bone alongside the sinocranial border. Ommaya *et al.* suggest that the pressure of CSF in the arachnoid pouch could cause erosion of the thin sellar floor [1]. O'Connell advanced acquired nature of nontraumatic CSF rhinorrhoea due to a fistula in the lamina cribrosa over which he found a pulsating pocket of CSF [31]. A similar hypothesis is mentioned for sphenoid sinus leaks [2, 3, 19, 32, 33]. It is believed that extensive lateral pneumatization of the sphenoid sinus into the greater wings and pterygoid process, together with the presence of arachnoid villi pits in the bottom of the middle fossa, is capable of creating bony erosion over the course of many years. Patients with sphenoid spontaneous CSF leaks reveal higher incidence of extensive lateral pneumatization and the presence of arachnoid pits lateral to V2 when compared to patients without CSF leak (lateral recess 91–100% vs. 23–35.3% and 63–100% vs. 0–23.4% arachnoid pits respectively) [3, 19].

Interestingly, all articles presenting cases related to Sternberg's canal revealed a spontaneous CSF leak together with cephalocele within the sphenoid sinus, protruding through relatively small bony defects. This observation is considered to be an indicator of acquired nature of the lateral recess defects [2, 34]. Other clinical features observed in lateral sphenoid leaks, such as the presence of an empty sella, female sex, middle age, and obesity, may suggest the role of attenuated CSF circulation/pressure as a potential risk factor [2, 32, 34–41] (Table I). Relations between spontaneous CSF leaks and cephaloceles within the sphenoid sinus and benign intracranial hypertension need further investigation.

Management of CSF leaks and meningoencephaloceles in the sphenoid sinus is debated by various specialists according to their experience. Differences are described in surgical approach, reconstruction methods and adjuvant strategies (lumbar drainage, image guidance, application of fluorescein). Among traditional, wide approaches, transcranial and transpalatal surgery have been discussed. Recently, due to technical development, endoscopic techniques have been favored instead of transcranial and transpalatal approaches.

Surgical treatment of CSF leaks in the lateral recess of the sphenoid sinus can be a surgical dilemma even for the most skilled surgeons because of the difficulties in gaining adequate access to this area [18]. Factors determining the choice of approach include the degree of lateral pneumatization of the sphenoid sinus, location and size of cephalocele, and ability to perform an adequate skull base repair through a given exposure [21].

In the past, transcranial approaches have been commonly used for surgical management of sphenoid sinus lateral recess pathology. They were performed through the pterional route or through the middle fossa (fronto-spheno-temporal approach) and were used to repair encephaloceles within the lateral recess of the sphenoid sinus. Fronto-spheno-temporal craniotomy provides a good access for exploration of the middle cranial fossa floor. Disadvantages of this approach include a large external incision, temporal lobe retraction, intensive care unit monitoring, and seizures afterwards. However, in transcranial surgery the burden of central nervous system infection is thought to be smaller than in endoscopic

Table II. Surgical treatment of analyzed case series

No.	Author year	No. of cases	Surgical approach	Skull base reconstruction technique	Lumbar drainage	Complications	Recurrence
1	Bernstein 1997 [15]	2	External ethmoidectomy (Lynch incision)	Fascia + abdominal fat obliteration	Yes	No	1 pt
2	Schick 2000 [9]	1	Transcranial pterional (fronto-temporal) approach	Abdominal fat (bottle neck fashion)	No data	No	No
3	Blaivie 2006 [17]	1	Endoscopic endonasal: TS	Septal cartilage, duraplasty + abdominal fat obliteration + 2nd layer of septal cartilage	No	No	No
4	Castelnuovo 2007 [18]	15	Endoscopic endonasal: TS – 6 pt TESPA – 9 pt	Obliteration with abdominal fat – 6 pt Multilayer: Middle turbinate bone and mucoperiosteum, nasal septum cartilage, mucoperiosteum; dural substitute	No		No
5	Tomazic 2009 [20]	5	Endoscopic endonasal: TESA – 2 pt TESPA – 3 pt	Multilayer Abdominal fat in "bath-plug" fashion Fascia lata overlay; fibrin glue	No	Meningitis – 1 pt Brain abscess – 1 pt	2 pt Endoscopic revision surgery
6	Tabaee 2010 [21]	13	Endoscopic endonasal: 1. TS 5 2. TESA 5 3. TESPA 3	Multilayer Bone, fascia lata or temporalis, mucoperiosteal flap, abdominal fat, cartilage Dural substitute – different combinations	8 pt – yes	Meningitis – 1 pt Facial paresthesia – 1 pt	1 pt – endoscopic revision surgery 1 pt – spontaneously stopped
7	Bendersky 2011 [23]	2	Transcranial (fronto-temporal) 1 pt (after 3× endoscopic approach) 2 pt (after 1x endoscopic approach)	Multilayer 2 layers of dural graft bone	No data	no	No recurrence after transcranial approach
8	Izquierdo 2012 *Abstract* [25]	1	Endoscopic TESPA	No data in English	No data in English		No data in English
9	Samadian 2012 [22]	1	Transcranial	Multilayer Cranial bone, temporalis fascia	No data	No	No
10	Maselli 2012 [24]	1	Endoscopic endonasal: TS	Multilayer Abdominal fat "bottle-neck" fusion + muscle + fibrin glue	No data	No	No
11	Sanjari 2013 [26]	1	Endoscopic endonasal	Fat + pediculated mucosal flap	None after surgery	No	Twice 1 week and 1 year after surgery – lumbar drainage applied

TS – Transnasal (transsphenoidal), TESA – transethmoidal-sphenoidal, TESPA – transethmoidal-sphenoidal-pterygoidal, pt – patient.

surgery because it allows the surgeon to reach the defect through a more sterile operative field [42].

Among endoscopic techniques, three modalities have been applied according to the localization of changes with respect to the midline: the transsphenoidal approach (transnasal approach), the TESA and TESPA [18, 20, 21, 43]. The CSF leaks close to the midline can be managed with the transsphenoidal approach or transethmoidal-sphenoidal approach. Extensive lateral pneumatization of the sphenoid sinus and lateral recess CSF leak require either the TESA or the TESPA.

The transsphenoidal approach involves enlargement of the natural sphenoid ostium in the superior meatus and creation of a common cavity incorporating both ostia with removal of the posterior portion of the nasal septum. Angled endoscopes inserted on the contralateral side allow improved visualization of the lateral wall of the sphenoid sinus. Skull base reconstruction methods involve different strategies of plugging the dehiscence. Prior reports described obliteration of the sinus with a fat graft without a specific skull base reconstruction [18, 21]. This option can be used in small sphenoid cavities where accurate removal of mucosa can be achieved, but unfortunately CSF leaks usually arise in well-pneumatized bones. The relapse of CSF leak and mucocele formation associated with this method has led surgeons to widening of the corridor (TESA, TESPA) to obtain appropriate visualization of the osseodural defects, enabling an efficacious skull base reconstruction.

The transethmoidal-sphenoidal approach is required in cases of lateral pneumatization of the sphenoid sinus. It involves anterior and posterior ethmoidectomy with a large sphenoidectomy. This may be combined with a transsphenoidal approach providing additional lateral exposure [21]. For lesions localized far laterally, TESPA is considered a preferable method. It allows better control over the lateral recess of the sphenoid sinus while sparing important anatomic structures and minimizing surgical mortality and morbidity [18, 43]. The surgeon reaches the lateral recess through the posterior wall of the maxillary sinus and pterygopalatine fossa. Opening the pterygopalatine fossa accesses the sphenopalatine and maxillary arteries, V2 and Vidian nerve. Careful cauterization of the arteries and preservation of the nerves should always be attempted [20]. Mucosa and periosteum around the defect have to be removed to create an effective receptor site for grafts. Reconstruction techniques of the skull base combine underlay and overlay techniques (multilayer techniques) with both auto- and allogenic materials [18, 20, 21] (Table II).

The advantages of the endoscopic approach include less traumatic character, without a large external incision, and temporal lobe retraction, thus minimizing brain manipulation [18, 42, 44, 45]. The disadvantages of endoscopic techniques involve their challenging character, especially when the TESPA approach is applied. A potential risk for significant complications includes persistent CSF leak, neurovascular injuries and meningitis. Castelnuovo *et al.* advise using a four-hand technique when possible [18].

The first of our patients was closed with TESA performed 10 years prior to the second one (TESPA). The time gap between those two let us gain more experience followed by acquiring more sophisticated tools to perform this type of surgical procedure.

Conclusions

Cephaloceles within the sinus and extensive lateral recess are typical radiological findings in cases of sphenoid sinus CSF leaks. Complex ontogenesis of sphenoid bone which creates the lines of lesser resistance within the bone may be responsible for this phenomenon. Taking into account all controversies about the origins of spontaneous sphenoid sinus CSF leak, we can hypothesize that developmental conditions such as Sternberg's canal and extensive lateral pneumatization of the sphenoid sinus together with pathological conditions involving intracranial hypertension and arachnoid pits underlie the pathology.

Over the last three decades, the approach has become less invasive due to application of endoscopic transnasal techniques, leaving patients without large scars and with good results. A small sphenoid sinus (i.e. without extensive lateral pneumatization) requires the transethmoidal sphenoidal approach, whereas lateral extension of the sinus should lead the surgeon to apply the TESPA.

Conflict of interest

The authors declare no conflict of interest.

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