ORIGINAL ARTICLE

Sialolithiasis Management

The State of the Art

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Sialolithiasis is the main cause of unilateral diffuse parotid or submandibular gland swelling. Its incidence has been poorly studied but seems to be much higher than the classic data published by Rauch of 1 case per 300000 people per year.[1] In a recent study, based on hospital admission figures in England, Escudier and McGurk[2] estimated this incidence to be between 1 per 15000 and 1 per 30000. Personal observations of an incidence between 1 per 10000 and 1 per 20000 seem to confirm these results (F.M. and P.D., unpublished data, 2002). Sialolithiasis results in a mechanical obstruction of the salivary duct, causing repetitive swelling during meals, which can remain transitory or be complicated by bacterial infections.[3,4] Traditionally, recurring episodes necessitate treatment by open surgery, and sialolithiasis still represents the most frequent reason for submandibular gland resection.[5,6] Interestingly, parotid gland resection remains less frequent, probably because of the higher incidence of postoperative complications such as facial paresis.[7]

In the early 1990s, several authors have attempted to cure sialolithiasis conservatively. Radiologists dealing with sialoliths during sialography have attempted retrieval of these stones using a Dormia basket either blindly[8] or under sialographic control.[9,10] Initial attempts to explore salivary ducts were also performed during the same period,[8,11] but equipment limitations precluded adequate visualization. Others, inspired by urologic techniques, developed extracorporal lithotripsy for sialolithiasis.[12] Although endocannular lithotripsy was also available,[11] a lack of adequate instrumentation prevented complete ductal exploration and treatment. Thanks to major advances in optical technologies, complete exploration of the salivary ductal system and a precise evaluation of its pathologic state are now possible. Sialendoscopy,[13,14] or sialoendoscopy[15] as it is called by others, is therefore a new procedure, aiming to visualize the lumen of the salivary ducts to diagnose and treat ductal diseases. The objective of this article is to review the existing diagnostic and interventional modalities for sialolithiasis management.

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PHYSIOPATHOLOGIC CHARACTERISTICS

Sialolithiasis is composed of varying ratios of organic and inorganic substances. The organic substances are glycoproteins, mucopolysaccharides, and cellular debris.[16] The inorganic substances are mainly calcium carbonates and calcium phosphates. Calcium, magnesium, and phosphate ions each comprise between 20% and 25%, with other minerals (manganese, iron, and copper) making up the remainder. The chemical composition consists mainly of microcrystalline apatite ($Ca^5[PO_4]^3OH$) or whitlockite ($Ca^3[PO_4]$).[2,17] Apatite is the most prevalent component present throughout the stone, while whitlockite is mainly found in the core.[17,18] The formation depends on the concentrations of calcium and phosphorus, with low concentrations favoring the formation of apatite and high concentrations favoring whitlockite.[19] Other crystalline forms include brushite and weddellite, which are present in small amounts, mainly at the periphery of sialoliths.[17] These may be initial forms of calcium deposition, followed by subsequent remodeling into apatite.[17]

Often, the organic substances predominate in the center of the stone, while the periphery is essentially inorganic.[16,17] Scanning electron microscopy has demonstrated oval, elongated shapes, suggesting the presence of bacilli in sialoliths.[20] A recent polymerase chain reaction study[21] found bacterial DNA, mainly of oral commensals belonging to the *Streptococcus* genus, in all examined sialoliths.

The exact pathogenesis of sialolithiasis remains unknown, and various hypotheses have been proposed.[16] The first is based on the existence of intracellular microcalculi that, when excreted in the canal, may become a nidus for further calcification.[22,23] The second hypothesis suggests that aliments, substances, or bacteria present within the oral cavity may migrate into the salivary ducts and become the nidus for further calcification.[24] Both hypotheses presuppose an initial organic nidus that progressively grows by the deposition of layers of inorganic and organic substances.

According to most published data,[2,3] salivary stones are localized in the submandibular gland in 80% to 90% of sialolithiasis cases. In our experience, parotid glands are affected more frequently (in up to 40% of cases), a difference possibly explained by the sensitivity of the new detection methods used.[25,26] This may also explain a high incidence of multiple sialolithiasis that was found in 58% (29/50) of parotid[26] and 29% (31/106) of submandibular[25] affected glands. The annual growth rate of established salivary stones has been estimated to be 1 mm per year.[27] They vary in shape, being round or irregular. According to 2 recent studies,[25,26] the size ranges from 2 mm to 2 cm, with the mean being 3.2 mm and 4.9 mm for parotid and submandibular stones, respectively, a finding that emphasizes the need for fragmentation before extraction of these stones.

The etiologic agents responsible for sialolithiasis remain elusive. Sheman and McGurk[28] attempted to correlate the geographic distribution of water hardness and salivary calculi. This study indicated no link between water hardness and sialolithiasis or sialadenitis, suggesting that high calcium intake might not lead to salivary calculi. In rats, experimentally induced hypercalcemia failed to result in sialoliths.[29]

There is a recent interest in the effects of tobacco on saliva. Tobacco smoking has been shown to result in an increased cytotoxic activity of saliva, a decreased polymorphonuclear phagocytic ability, and a reduction of salivary amylase, including salivary protecting proteins, such as peroxidase.[30] If cigarette smoking impairs the phagocytic and protective functions of saliva, the hypothesis of a link between infection and sialolithiasis could be favored. In a recent epidemiological study examining the nutritional habits and other behaviors of patients with sialolithiasis, tobacco smoking was found to be the only positive correlation with the disease (M. Oedman, MD, unpublished data, 2002).

RADIOLOGICAL DIAGNOSTIC APPROACHES

Standard x-Ray Films

The classic occlusal film effectively shows ductal stones, while intraglandular and small stones can be missed.[31] According to an early report by Rauch and Gorlin,[27] only 20% of sialoliths are radiotransparent; hence, this method should only be used for screening when no other method is available.

Computed Tomographic Scan

Often performed, computed tomographic scan is adequate for diagnosing sialolithiasis only if the stone is large or if radiological slices are performed every millimeter. Among the disadvantages are the lack of precise localization of the stone and the absence of visualization of the ducts and their anomalies.[32]

Ultrasonography

Ultrasonography (US) is a noninvasive method of diagnosis, especially popular in Europe.[33,34] Unfortunately, US is operator-dependent, with no directly interpretable image for the surgeon, unless the surgeon is doing the examination. In addition, US has limitations for detection of sialolithiasis. A study[35] comparing US, sialography, and endoscopy demonstrated a sensitivity of 81%, a specificity of 94%, and an accuracy of 86% for US. In a study comparing magnetic resonance (MR) sialography and US, Jäger et al[34] found a specificity and sensitivity of 80% for US.

Sialography: The Old "Gold Standard"

Sialography consists of an opacification of the salivary ducts by a retrograde intracannular injection of water-soluble radiopaque dye. Sialography is considered the gold standard because it provides a clear image not only of the stones but also of the ductal morphologic structure. It can also provide images that are diagnostic for certain conditions, such as Sjögren disease.[36] Sialography was described to have the advantage of being therapeutic, with the injection of dye producing a dilatation of the duct that results in the excretion of the stone. Nevertheless, the success of therapeutic sialography has never been documented. Disadvantages include the irradiation doses, pain associated with the procedure, possibility of canal wall perforation, and complications of infection and anaphylactic shock.[37] In addition, sialography often tends to push the stone farther up the canal, a distinct disadvantage if a removal by sialendoscopy is planned.

MR Sialography: A New, Noninvasive Technique

Magnetic resonance sialography is a new diagnostic procedure, with promising results. It consists of 3-mm T2-weighted fast spin–echo slides, performed in the sagittal and axial planes. Volumetric reconstruction is then performed, allowing a visualization of the ducts and their condition. The advantages include a rapid, totally noninvasive technique, no dye injection, no irradiation, and no associated pain. The disadvantages are (1) the 45 minutes required for the reconstruction (although the acquisition time is 10 minutes); (2) MR imaging–associated inconveniences such as equipment costs, ferromagnetic implants, and examination intolerance by claustrophobic patients; and (3) limitations because of artifacts resulting from dental bridges.[38] This new technique has been shown to be an excellent radiological technique for sialolithiasis.[34,38,39]

A NEW APPROACH: DIAGNOSTIC SIALENDOSCOPY

Diagnostic sialendoscopy is a recently described[13,40] procedure that allows an almost complete exploration of the ductal system, including the main duct and secondary and tertiary branches (**Figure 1**). This is possible thanks to the most recently manufactured endoscope (Karl Storz, Tübingen, Germany), which has a small outside diameter (2 channels of respectively 0.9- and 1.3-mm diameter) and incorporates a rinsing channel, necessary for dilatation of the ductal system and for cleaning and rinsing of the debris during the procedure. The need for a semirigid system has been demonstrated by the difficulty in directing a flexible system without a mobile tip and its fragility and poor image quality.[25,26] Among the last 450 endoscopies we performed, diagnostic sialendoscopy was achieved in 98% of cases, while others report a 96% success rate.[40] Rare limitations include an extremely tortuous canal that could hamper endoscope progression and difficulties in directing the endoscope at the distal end of the canal system.

Sialendoscopy can be done as an outpatient procedure in the clinic with the patient sitting in a chair or partially recumbent. Local anesthesia is used. Progressive dilatation of the papilla is performed with salivary sounds of progressively larger diameters. Endoscopy is performed with progressive endoluminal irrigation using a local anesthetic solution. The diagnostic and interventional sialendoscope that we recommend (1.33-mm^2 surface and 1.3-mm diameter) provides excellent vision and is suitable for both diagnostic and interventional procedures.

Sialendoscopy provides direct, reliable information about most ductal pathologic conditions and reduces the need for radiological investigations. The indications for diagnostic sialendoscopy are all intermittent salivary gland swellings of unclear origin.[41] There are no specific contraindications, mostly because sialendoscopy is a minimally invasive, outpatient procedure performed under local anesthesia. Even children[42] and senior populations are suitable candidates for this technique.

Despite its apparent simplicity, sialendoscopy is technically challenging. Operating the rigid sialendoscope is delicate, requires experience, and may be hazardous because of theoretical risks of perforation and vascular or neural damage. Progression in the canal should be completely atraumatic and performed only under adequate vision. Significant trauma to the ductal wall could result in subsequent stenosis. Marsupialization of the ductal papillae should be avoided or kept as small as possible to prevent retrograde passage of air and aliments. Perforations of iatrogenic origin outside the gland can lead to diffuse swelling of the floor of mouth, with potential risk of life-threatening swelling.

In conclusion, diagnostic sialendoscopy is an outpatient evaluation procedure, performed under local anesthesia, with proven efficacy.[13-15,25,26,40,43-45] It is largely replacing the classic radiological investigation methods, such as sialography, which until recently was the gold standard.

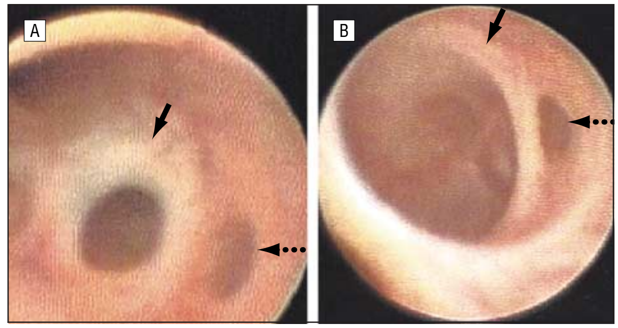

Figure 1. Sialendoscopic view before (A) and after (B) stenosis dilatation of a tertiary division of Stensen duct. The thick arrows show the stenotic area that was dilated. The fine dashed arrows show the departure of the same ductal branch.

CLASSIC THERAPEUTIC APPROACHES

The classic treatment of sialolithiasis is antibiotics and anti-inflammatory agents, hoping for a spontaneous stone expression through the papilla. In cases of submandibular stones located close to Wharton papillae, a marsupialization (sialodochoplasty) is performed and the stone removed.[46,47] Interestingly, although sialolithiasis is the most frequent reason for submandibular gland resection,[48] stones are often left in the Wharton duct remnant.[6] In cases of posterior-located submandibular or parotid stones, a conservative approach is adopted whenever possible, probably because parotidectomy for infectious conditions is associated with a high incidence of facial nerve complications.[7]

It is commonly believed that a gland with sialolithiasis is no longer functional.[49] A recent study[49] on submandibular glands removed because of sialolithiasis demonstrated the following: (1) there was no correlation between the degree of gland alteration and the number of infectious episodes; (2) there was no correlation between the degree of gland alteration and the duration of evolution; and (3) despite appropriate indications for submandibular gland removal, close to 50% of the removed glands were histopathologically normal or close to normal. A conservative approach even in long-standing sialolithiasis appears therefore to be justified.

External lithotripsy, initially reported by Iro and colleagues[12] in the early 1990s, is becoming popular but requires several sessions at intervals of a few weeks. Once fragmented, stones are expected to evacuate spontaneously since no stone extraction is described with this technique. The remaining stone debris can be seen as the ideal nidus for further calcification and sialolithiasis recurrence. Success rates up to 75% for the parotid and up to 40% for the submandibular gland are reported[50-54] and are similar for external and intracannular lithotripsy.[50] Although sialendoscopy might be adapted as an adjuvant procedure to external lithotripsy to retrieve the fragments, we see little use in de novo investing in the ex-

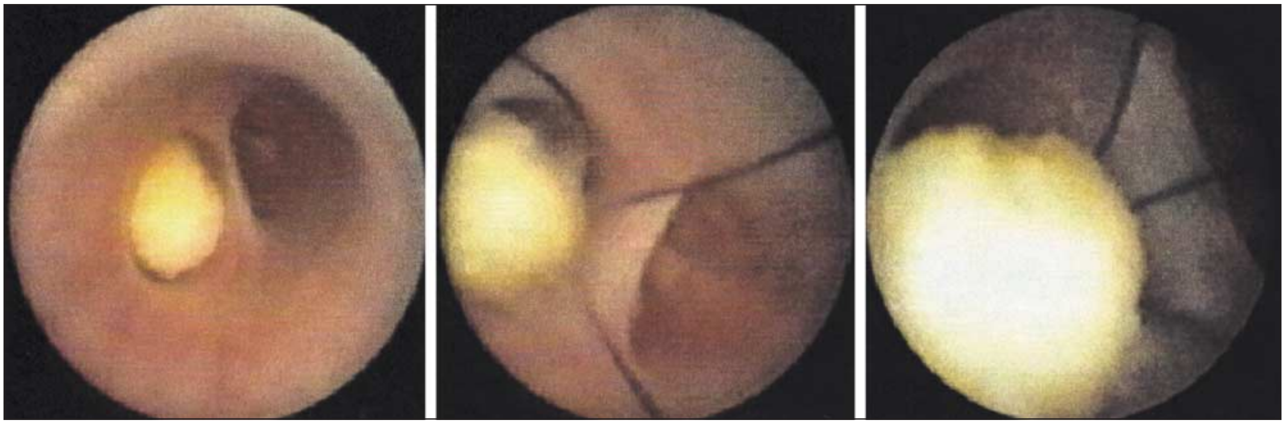

Figure 2. Sialendoscopic stone retrieval by a grasping basket.

pensive equipment. In addition, these techniques could result in significant damage to the gland.

Other techniques for sialolithiasis fragmentation have been described, such as those using electrohydraulic[55] and pneumoblastic[56] devices. Electrohydraulic devices, initially described as promising,[55] have been proven to be of low efficacy at low voltages. Although we have found that at higher voltages destruction of stones was possible, injuries of the canal wall have been described and the technique criticized.[57] Pneumoblastic devices are based on the delivery of mechanical energy to the stone. Although no clinical trials using this technique for salivary stones have been published, in vitro investigations tend to emphasize the risks of canal wall perforations.[56]

INTERVENTIONAL SIALENDOSCOPY

The literature on Stensen duct sialendoscopy is limited, as most series report on parotid as well as submandibular sialolithiasis. Probably, the smaller diameter of the Stensen duct[58] has made its exploration more challenging. Previous authors[8] have performed blind endoscopic stone retrieval with a Dormia basket (**Figure 2**), corresponding possibly to a "endoscopically-assisted stone retrieval" but not to interventional sialendoscopy. Although we initially used this method, we no longer recommend this procedure because of the blindness of the technique and the potential risks of perforation and ductal lesions.

Five generations of endoscopes have been developed and evaluated.[25,26] Our first attempts to perform stone extraction under endoscopic control were done with a flexible fiberscope, which we have abandoned, not only because of difficult maneuvering and poor visualization but also because of fragility, difficulty in sterilization of the material, and frequent "stripping" of the internal coating of the working channel by the grasping wire basket. Satisfactory results were obtained with semirigid endoscopy, which initially consisted of the juxtaposition of 2 tubes. Because of the size of the instrument relative to the ductal lumen, progression within the canal was difficult and resulted in ductal wall tears. The present instrument (Marchal sialendoscope; Karl Storz, Tuttlingen, Germany) measures 1.3 mm in diameter and contains an optic fiber of 6000 pixels (a minimum for adequate image quality), a rinsing channel of 0.25 mm, and a working channel of 0.65 mm for instrumentation.

The results of interventional sialendoscopy are directly related to the size of the stones in the submandibular and parotid glands. Sialolithiasis can either be round or exhibit sharp edges. In our hands, round stones are associated with an easy retrieval, while stones with edges are often embedded in the canal wall. In parotid sialoliths, size is probably the most important factor in predicting the success of interventional sialendoscopy. One study[26] reported that 97% of stones smaller than 3 mm could be retrieved with the wire basket, without fragmentation, while for larger stones the success of this technique was 35%. For these sialoliths, fragmentation before extraction is necessary.

In our opinion, the best system is the fragmentation of sialoliths using a fiber-optic laser, as initially described by Gundlach et al.[11] The laser is introduced into the sialendoscope, laser sialolithotripsy is performed under direct visual control, and retrieval of stone fragments is achieved with grasping wire baskets. An advantage is the retrieval of sialoliths and their fragments after lithotripsy, which is absent from most previously described methods.[11,56,57,59]

The holmium laser is well known and has proven efficacy for urolithiasis.[60,61] However, one has to be attentive to its potential dangers, because of its absorption characteristics in the surrounding tissues and because of the heat generated from the fragmentation within the narrow salivary ducts (**Figure 3**). It should be used only under clear vision, tangential to the duct, and only in cases of sialolithiasis. The dye laser[11] has proven efficacy and low morbidity, as the high energy delivered is not absorbed by the tissues. Unfortunately, the cost of the device and its specificity may render its acquisition difficult.

Among 450 submandibular and parotid endoscopies, we have not encountered any significant complications, such as damage to the facial or lingual nerves, gross hemorrhage, or major canal wall perforations. Nevertheless, minor canal wall perforations have been observed, leading to hospitalization because of swelling of the floor of mouth. Blockages of the grasping basket in 5 cases, requiring firm traction under general anesthesia for retrieval, and ruptures of the basket in 3 cases, none

Figure 3. Sialendoscopic laser fragmentation of a submandibular stone and fragment retrieval with a grasping basket.

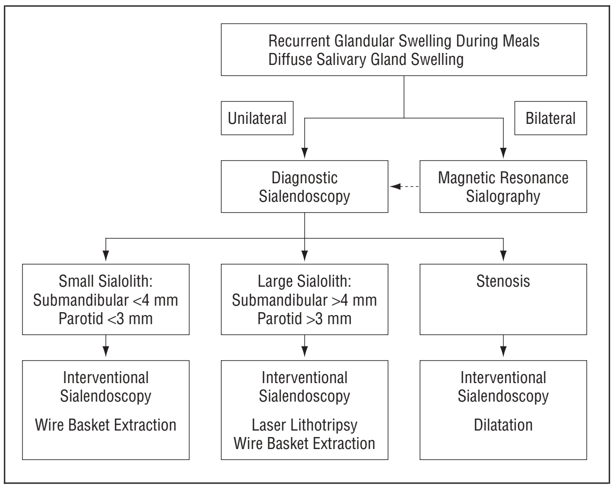

Figure 4. Decision tree for the evaluation and management of sialolithiasis.

requiring gland resection, also have occurred. These are traumatic experiences for the patient and the surgeon, potentially resulting in emergency submandibular gland resection, and should advocate for an extreme cautiousness in the use of the grasping basket.

DECISION TREE

The approach toward unilateral salivary gland swelling (**Figure 4**) is the same for the submandibular and parotid glands, although the smaller diameter of the parotid ductal system renders the procedure more challenging. Once a clinical suspicion of a ductal obstruction is present, we tend to favor diagnostic sialendoscopy as the initial procedure of choice, mainly because of its minimally invasive nature and excellent patient acceptance. In cases of multiple glandular symptoms or unclear clinical presentation, MR sialography should be performed so that the texture of the gland, surrounding tissue, and ductal system of several salivary glands can be assessed.

If diagnostic sialendoscopy reveals 1 or more stones (or other ductal pathologic conditions, such as stenosis), the interventional procedure can be conducted in the same setting. For small stones less than 4 mm in diameter in submandibular cases and less than 3 mm in parotid cases, extraction is performed with custom-designed wire baskets of various sizes. In cases of bigger stones, prior fragmentation is necessary using an external lithotriptor or, preferably, a dedicated laser system. Stenoses are treated with metallic dilators when located in the main duct or with balloon catheters under endoscopic control for localized or more peripheral strictures.

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