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Simultaneous Application of Ultrasound and Sialendoscopy and its Value in the Management of Sialolithiasis

Simultane Anwendung von Ultraschall und Sialendoskopie: Wertigkeit in Diagnostik und Therapie von Speichelsteinen

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ABSTRACT

Objective Ultrasound (US) and sialendoscopy (SE) are routinely used in patients presenting with sialolithiasis in the submandibular (SMG) and parotid gland (PG). The objective was to assess the value of the simultaneous application of US and SE in the management of sialolithiasis.

Study Design Retrospective study. Setting: Tertiary referral center for salivary gland diseases. Participants: Patients in whom US and SE as single investigation tools were neither conclusive nor useful in the management of sialolithiasis were investigated using both methods simultaneously (simUS + SE). Main outcome measures: Establishment of the final diagnosis and/or contribution to the planning/performing of treatment in sialolithiasis.

Results 74 patients were examined by simUS + SE (58.1 % SMG and 41.9 % PG). In all patients (unclear) hyperechoic reflexes were assessed and/or localized by SE-controlled US navigation. 68.9 % of the patients were investigated for diagnostic or differential-diagnostic reasons including distinguishing extraductal from intraductal calcifications and/or to exclude residual stones after therapy. In 52.7 % simUS + SE was used to plan and/or perform further treatment, in 20.3 % to enable performing a combined approach (all PG) and in 29.7 % to evaluate and plan the most adequate therapy (mainly intraductal vs. extracorporeal shock wave lithotripsy, 68.2 % of these SMG). In two cases SE-controlled and US-guided stone extraction was performed.

Conclusion SimUS + SE is an innovative approach which proved to be very useful in managing sialolithiasis. It added valuable information regarding the establishment of a diagnosis or differential diagnosis, planning and performing the most adequate treatment, intraoperative control of therapy and postoperative follow-up.

ZUSAMMENFASSUNG

Ziel Ultraschall (US) und Sialendoskopie (SE) werden routinemäßig bei Patienten mit einer Sialolithiasis der Glandula submandibularis (GSM) und Parotis (GP) angewendet. Ziel war es, den Wert der simultanen Anwendung von US und SE (simUS + SE) für die Sicherung der endgültigen Diagnose und/oder ihren Beitrag zur Planung und Durchführung der Therapie der Sialolithiasis zu untersuchen.

Material und Methoden In einer retrospektiven Studie wurden Patienten, bei welchen US und SE als einzelne Untersuchungsmethoden kein sicheres Ergebnis erbrachten, auf den Mehrwert einer simUS + SE hinsichtlich des weiteren Managements untersucht.

Resultate Bei 74 Patienten erfolgte eine simUS + SE (58,1 % GSM und 41,9 % GP). Bei allen Patienten wurden (unklare) echoreiche Reflexe mittels Navigation durch US und SE evaluiert und/oder exakt lokalisiert. In 68,9 % der Fälle erfolgte die simUS + SE, um die Diagnose zu sichern bzw. mögliche Differenzialdiagnosen abzuklären. In 52,7 % wurde der simUS + SE benutzt, um die weitere Therapie zu planen und/oder durchzuführen. In 29,7 % aller Fälle half die simUS + SE, die am besten geeignete Therapie (insbesondere intraduktale vs. extrakorporale Schockwellen-Lithotripsie) auszuwählen, in 68,2 % dieser Fälle war die GSM betroffen. In 20,3 % konnte sicherer beurteilt werden, ob eine kombinierte Steinextraktion möglich oder sinnvoll war (alle GP). In 2 Fällen wurde eine US-gesteuerte und SE-kontrollierte Steinextraktion durchgeführt.

Schlussfolgerungen Die simUS + SE stellt eine innovative Untersuchung dar, welche sich als nützlich für das Management der Sialolithiasis erwiesen hat. Diese war wertvoll für die Sicherung der korrekten Diagnose oder Differenzialdiagnose, Planung und Durchführung der am meisten geeigneten Therapie, darüber hinaus auch bei der intraoperativen Therapiekontrolle und dem postoperativen Follow-up.

Introduction

Sialolithiasis is the most frequent cause of obstructive sialadenopathy, accounting for approximately 60–70 % of all cases and up to 20 % of cases of unclear duct dilation or gland swelling [1]. Sialolithiasis can be diagnosed using tools such as sialography [2], computed tomography (CT) [3], three-dimensional cone-beam computed tomography (3 D CBCT) [4], CBCT sialography [5], and magnetic resonance (MR) sialography [6–8], with a sensitivity and specificity of more than 90 %. However, these methods have inherent limitations and disadvantages, including radiation exposure, the need to administer a contrast medium, cost, and logistic effort.

Ultrasound (US) is a dynamic real-time method and is part of the diagnostic armamentarium in many units that deal with obstructive salivary gland diseases. Both the ductal system and the parenchyma can be assessed [9–14]. US has been used in these diseases with a sensitivity of 77–95 % and a specificity of 80–100 % [10, 12, 15–18]. Stones that are smaller than 3 mm, are poorly mineralized, and located distally or near the hilum are sometimes difficult to identify. Extinction of the ultrasound waves by the mandible may prevent the depiction of stones located in the distal part of Wharton's duct. Scarring and/or connective tissue, sialolithiasis not caused by intraductal or extraductal calcifications, and air bubbles may also lead to misdiagnosis [16, 17]. Enhancing the findings by stimulation with ascorbic acid [16, 17, 19] or transoral US [20] can improve the sensitivity and specificity of imaging. In comparison with a reference standard (direct stone detection), US and US supplemented by subsequent sialendoscopy resulted in the correct preoperative diagnosis of sialolithiasis in ≥ 95 % of cases [16, 17].

Sialendoscopy (SE) is able to detect stones that are not visualized with other imaging tools [1, 21], but it also has limitations in identifying intraparenchymal stones [22].

Both US and SE play a key role in the management of sialolithiasis, as they can be used for the initial diagnostic workup, accompanying all treatment modalities, and for follow-up investigations [23–27]. In specific situations, particularly in difficult and/or complicated sialolithiasis, US and/or subsequent SE proved to be insufficient.

The aim of the present study was to assess the value of the simultaneous use of US and SE (simUS + SE) in diagnosis and differential diagnosis (DD), treatment planning, measures accompanying the treatment including intra- and postoperative monitoring of treatment success in patients with sialolithiasis.

Methods

This retrospective study was carried out at the Department of Otorhinolaryngology, Head and Neck Surgery of the University of Erlangen–Nuremberg, Germany. Approval for the study was obtained from the local institutional review board of the Friedrich-Alexander University of Erlangen-Nuremberg, and informed consent was obtained from all study participants. The records for patients who had presented for the diagnosis and treatment of obstructive sialadenitis between October 2011 and May 2018 were evaluated. According to our routine management algorithms, US examination of the major salivary glands (submandibular gland (SMG) and parotid gland (PG)) was the first diagnostic examination in all patients. US was carried out using high-end devices (Siemens ACUSON S2000 and S3000; Siemens Medical Solutions USA Inc., Malvern, Pennsylvania, USA). A 9L4 transducer, a linear B-mode setting, a frequency of 6–9 MHz, and tissue harmonic imaging were used routinely. Stimulation of glandular secretion by oral administration of vitamin C was regularly used to enhance imaging in patients with unclear findings [23]. Video documentation was used to store the findings for reevaluation and to minimize examiner dependency. As a second examination, SE was performed using a set of sialendoscopes (Karl Storz Company, Tuttlingen, Germany) [23]. If indicated, treatment was performed as described previously [23, 24, 26]. SimUS + SE was performed in specific situations in which a clear result could not be achieved by US alone or with US and subsequent application of SE (e. g. in the presence of an extraductal pathology). Localizing of and navigating to an unclear hyperechoic reflex or suspected stone for diagnostic and/or therapeutic reasons was an indication in all cases.

In detail, the diagnostic indications were: firstly, to establish the diagnosis and DD of sialolithiasis in unclear intraductal hyperechoic reflexes [16, 17]; secondly, to differentiate between extraductal and intraductal calcifications/sialolithiasis; and thirdly, to assess the indication for supplemental imaging, if even simUS + SE was not conclusive. Exclusion of residual stones or fragments, particularly after intraductal lithotripsy (IDL) and/or extracorporeal shock-wave lithotripsy (ESWL), was the fourth diagnostic indication [27].

Therapeutic indications were mainly based on precise localization of and navigation to stones to allow detailed treatment planning and implementation [23, 26, 27]. The accessibility of a stone and precise position of the sialendoscope in relation to the stone were important parameters. The distance between the stone and the sialendoscope was measured at the intraductal and/or extra-

▶ **Table 1** Simultaneous ultrasound and sialendoscopy in patients with obstructive sialadenitis caused by sialolithiasis (n = 74)*: Number and stratification of the indications.

patients / **indication – sialolithiasis**	**patients glands total (n)**	**patients submandibular Gl. (n)**	**patients parotid Gl. (n)**
patients with number of indications > 1 – stone-location/navigation included (n)			
▪ n = 2	11	9	2
▪ n = 3	48	28	20
▪ n = 4	10	6	4
▪ n = 5	5	–	5
glands / **indication – sialolithiasis**	**glands total (n indications)**	**submandibular gl. (n indications)**	**parotid gl. (n indications)**
diagnosis or differential diagnosis of sialolithiasis	135	78	57
▪ location/navigation stone/unclear reflex	74	43	31
▪ diagnosis/DD intraductal hyperechoic reflex	47	31	16
▪ DD extra-/intraductal calcification	11	4	7
▪ indication of supplemental imaging	3	–	3
management of complications of sialolithiasis			
▪ abscess and/or fistula (current sialolithiasis)	2	2	–
planning of the therapy	37	15	22
▪ possibility of combined approach	15	–	15
▪ indication of treatment modality (ESWL vs. ISWL)	22	15	7
therapy			
▪ US-guided and SE-controlled stone retrieval	2	–	2
follow-up			
▪ residual/recurrent stone/fragment post-therapy	39	31	8
sialolithiasis – indications total	215 (100 %)	126 (58.6 %)	89 (41.3 %)
sialolithiasis – patients total	74 (100 %)	43 (58.1 %)	31 (41.9 %)

* In all patients ≥ 2 indications were investigated.

ductal location of the stone in order to evaluate treatment options. Firstly, treatment planning involved choosing the most appropriate treatment modality in difficult sialolithiasis – usually a choice between ESWL and IDL [23, 27]. Secondly, it included investigating the potential for a successful combined approach [23, 26]. Thirdly, management of complications caused by sialolithiasis (e. g., abscess or fistula) and fourthly, retrieval of stones with ultrasound-guided and sialendoscopy-controlled basket extraction were further indications.

During the diagnostic examination, one person was active, holding the sialendoscope in one hand and the ultrasound device in the other. If interventional therapy was carried out, simUS + SE was performed by two physicians, one holding the sialendoscope and working with the instruments, and the other maneuvering the ultrasound transducer for navigation.

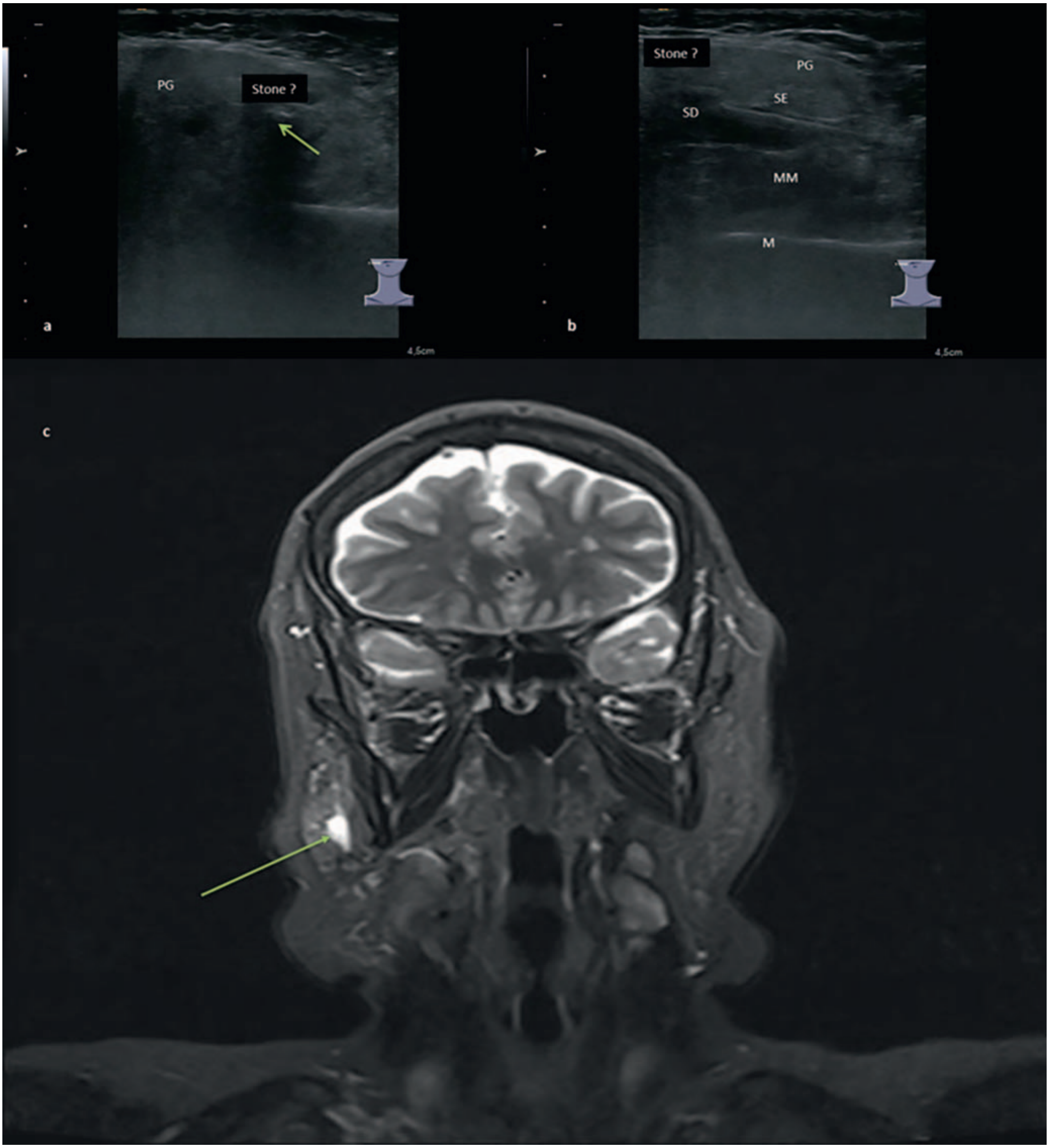
Statistical analysis was performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corporation, Armonk, New York, USA). Data are given as mean ± SEM, range, and median.

Results

74 patients who presented with sialolithiasis were included. The patients' mean age was 50.0 ± 15.1 years (M 52, range 16–86 y); 50 % were men and 50 % women (37/74). The PG was affected in 41.9 % of the patients (31/74) and the SMG in 58.1 % (43/74).

A total of 215 indications were investigated using simUS + SE – 126 in the SMG (58.6 %) and 89 in the PG (41.3 %). In all cases a stone or an unclear hyperechoic reflex was localized/navigated to using simUS + SE, but at least one additional question had to be solved to plan the further management. Diagnostic indications alone were investigated in 36 patients (48.6 %), therapeutic indications alone in 23 (31.1 %), and diagnostic and therapeutic indications in the same patient were assessed in 20.3 % (15/74 cases, ▶ **Table 1**).

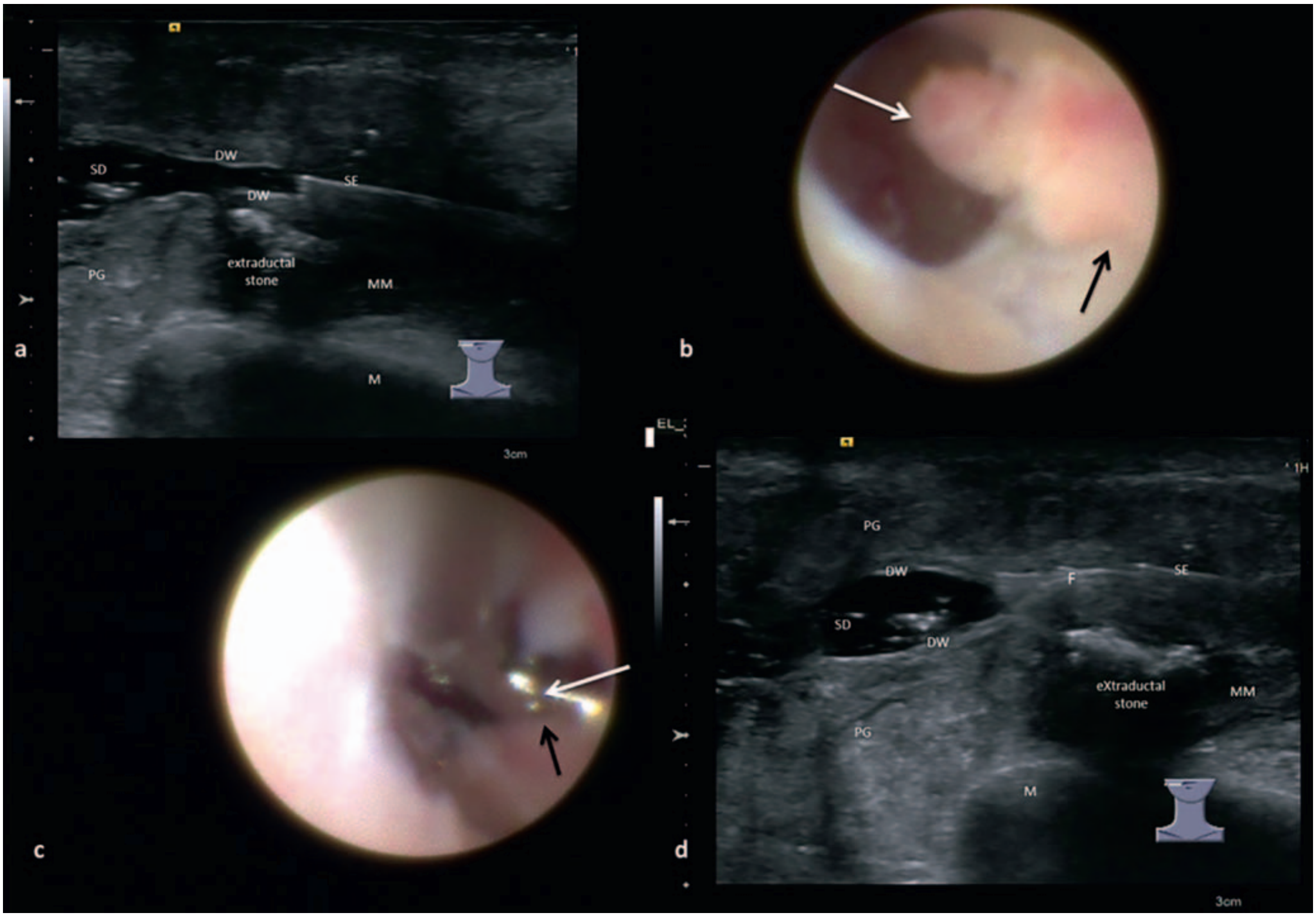
Pretreatment diagnosis and/or DD of sialolithiasis was investigated in 47 patients (63.5 %). Differentiation of extraductal and intraductal reflexes/calcifications was useful to differentiate extraductal sialolithiasis (n = 11, ▶ **Fig. 1a–c, 2a–d**) from non-sialolithiasis-related extraductal calcifications (n = 5, ▶ **Table 1**). The latter were identified as a calcified lymph node (n = 1, PG), calcified



► **Fig. 1 a–c** Ultrasound (US) view, showing a hyperechoic reflex with distal extinction and suspicion of a stone (**a**, green arrow, left). Simultaneous ultrasound and sialendoscopy (simUS + SE): the US view shows the sialendoscope located within a hypoechoic band-like structure (Stensen's duct), with a stone not visible – indicating that the hyperechoic reflex was located next to the duct **b**. Magnetic resonance imaging with T2 signaling reveals a space-occupying lesion within the parotid gland (green arrow, **c**) that does not correspond to sialolithiasis, but rather raises suspicion of an arteriovenous malformation **c**. PG: parotid gland; SD: Stensen's duct; MM: masseter muscle; M: mandible, SE: sialendoscope.

vessels (n = 2, one SMG, one PG), and vascular malformations (n = 2, both PG). In three cases additional MRI/MRI-Sialography was indicated because simUS + SE did not reveal the correct diagnosis (all PG; ► **Fig. 1a–c**).

Extraductal sialolithiasis, which mostly occurred after pronounced inflammation with or without abscess formation, was identified in six cases (n = 3 in SMG and PG each), which had an impact on the subsequent treatment in all cases (► **Fig. 2a–d**).



▶ **Fig. 2 a–d** Simultaneous ultrasound and sialendoscopy (simUS + SE): US view showing the sialendoscope within Stensen's duct above a hyperechoic reflex located beneath the ductal wall (**a**, right) and the corresponding sialendoscopic view without a visible stone, but with polypoid tissue (white arrow, **b**) above an extraductal stone (black arrow, **b**). After insertion of forceps, the sialendoscopic view shows the sialendoscope inside Stensen's duct, with the forceps (white arrow, **c**) positioned above the stone (black arrow, **c**) and the corresponding US view indicating that the stone is not accessible with the forceps due to its extraductal location **d**. Based on these findings ESWL was indicated for treatment of this stone. PG: parotid gland; SD: Stensen's duct; DW: duct wall; MM: masseter muscle; M: mandible, SE: sialendoscope; F: forceps.

Exclusion of residual stones/fragments including their differentiation from other intraductal hyperechoic structures after ESWL or IDL (▶ **Fig. 3a–c**) could be achieved in 39 patients (52.7 %, ▶ **Table 1**).

SimUS + SE was used to plan the most appropriate treatment and/or to perform it in 39 patients (52.7 %). In 22 patients (29.7 %) who presented with difficult primary or secondary sialolithiasis, simUS + SE helped to determine if ESWL or IDL was the most appropriate treatment. 68.2 % of these patients had sialolithiasis involving the SMG [27].

In 15 patients (20.3 %), simUS + SE helped to plan the adequate treatment in difficult and/or treatment-resistant sialolithiasis of the PG. If it was possible to access the stone with the sialendoscope or at least with an instrument, then a combined approach was offered with a real chance of success (▶ **Fig. 4a–d**, ▶ **Table 1**).

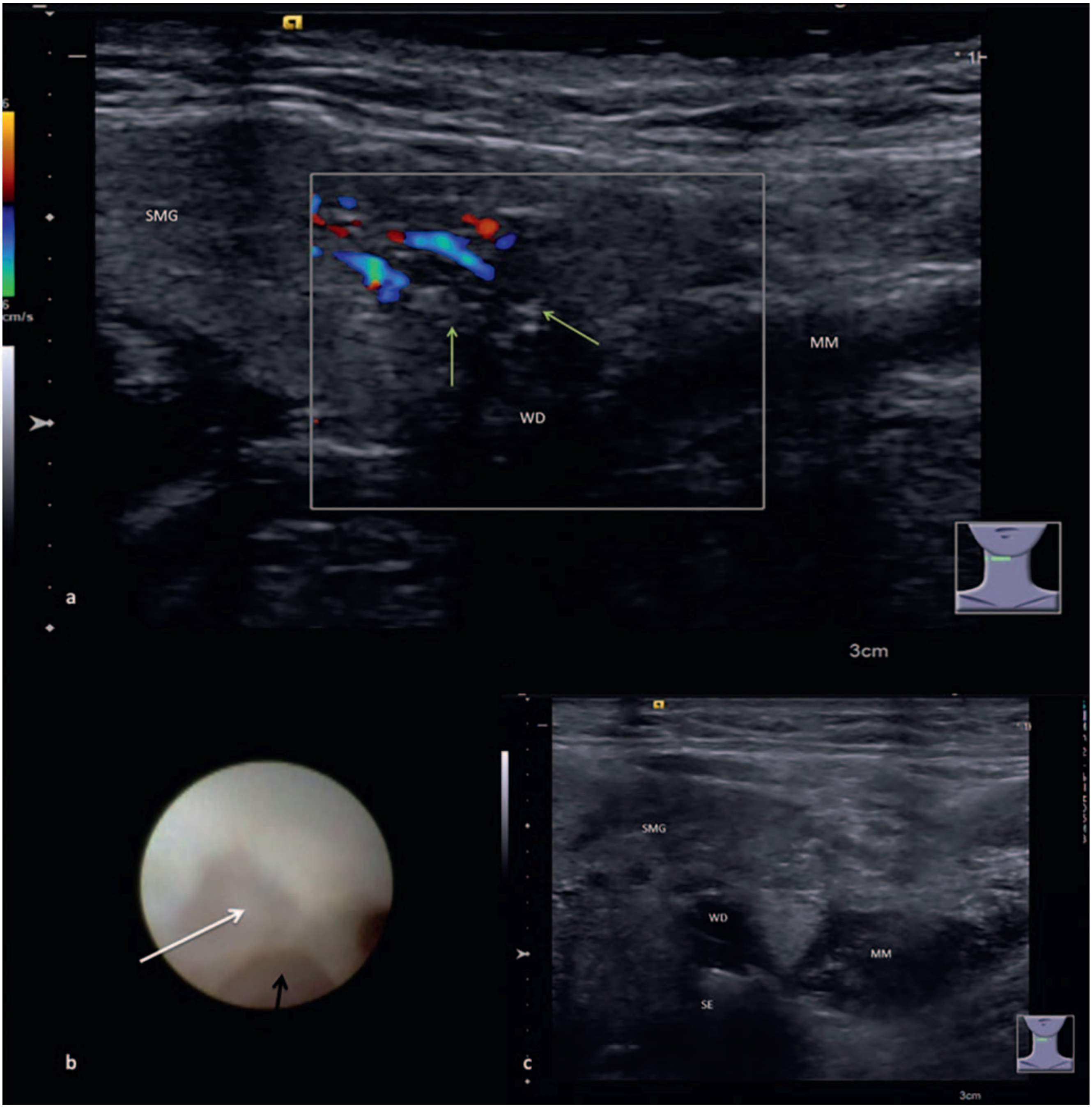
In two patients (both PG) who had a stone or fragment that was not adequately accessible with sialendoscopy, it was possible to remove the stone or fragment after the sialendoscope had been maximally inserted into the duct and a basket had been guided to the stone with US monitoring. Extraction of the stone or fragment was then carried out with sialendoscopic control and US guidance (▶ **Fig. 5a–d**, ▶ **Table 1**).

SimUS + SE was well tolerated by all patients and no complications were observed.

Discussion

US [9–15, 19, 26] and SE [1, 23, 24, 26, 27] were reported to be of value in the management of sialolithiasis. A strength of SE is with respect to unclear duct obstruction and/or occult sialolithiasis [1], but it has limitations regarding visualizing inaccessible intraparenchymal stones [22]. Such stones can be identified using US with a high sensitivity and specificity of ≥ 95 % [16]. The potential weakness of US could be reduced after supplementation by subsequent SE resulting in virtually maximal success rates [17].

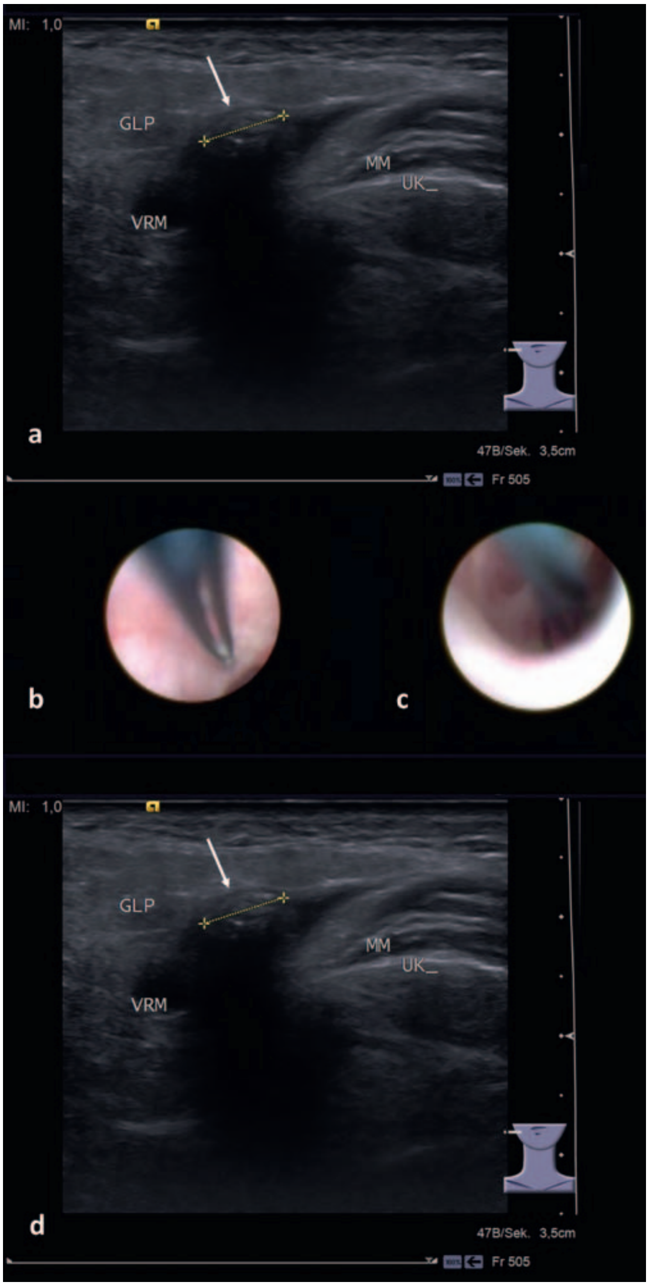
The data presented here indicate the excellent value of simUS + SE for diagnosis and/or DD, for planning and performing treatment, for post-treatment evaluation, and follow-up examinations in patients presenting with sialolithiasis. Application of simUS + SE



▶ **Fig. 3 a–c** Ultrasound (US) after intraductal lithotripsy in the right submandibular gland shows various small hyperechoic reflexes without clear shadowing (green arrows, **a**). Simultaneous ultrasound and sialendoscopy (simUS + SE): SE **b** and US **c** were used to identify scarring tissue (white arrow, **b**) at the duct wall (black arrow, **b**) and to rule out residual fragments as the cause of the small hyperechoic reflexes. The US view shows the sialendoscope in the corresponding part of Wharton's duct **c**. WD: Wharton's duct; SMG: submandibular gland; MM: mylohyoid muscle; SE: sialendoscope.

can further increase the information obtained by providing an excellent overview not only of the parenchyma but also of the intraductal and extraductal structures. SimSE + US thus uniquely allows three-dimensional visualization in real time. US findings can be further enhanced by administration of a stimulant (increasing centrifugal salivary flow), but much more by ductal dilation when SE is performed simultaneously (centripetal flow by the irrigation fluid). Used in all cases for diagnostic and/or therapeutic purposes, simUS + SE contributed to successful management of sialolithiasis in all patients.

SimUS + SE provided the final diagnosis or at least additional useful information for the diagnosis or DD of sialolithiasis in 68.9 % of all cases. It allowed the DD between sialolithiasis and competing intraductal reflexes (65.5 % of these were submandibular cases). SimUS + SE proved in particular to be useful to differentiate small (0.5–1.5 mm sized) residual fragments after IDL or



► **Fig. 4 a–d** Ultrasound (US) view showing a hyperechoic reflex with distal extinction, indicating an intraductal stone (white arrow, **a**) in the hilar duct, measuring 7 mm (dotted line, **a**). Simultaneous ultrasound and sialendoscopy (simUS + SE): the sialendoscopic view shows the tip of the basket before **b** and after **c** advancement into the proximal duct. The US view shows the basket in contact with the hyperechoic reflex (stone, white arrow, **d**). Because the instrument was in contact with the stone, a combined approach was indicated (and was later successfully performed). PG: parotid gland; VRM: retromandibular vein; SD: Stensen's duct; MM: masseter muscle; M: mandible, B: basket.

ESWL from competing intraductal hyperechoic reflexes not able to be differentiated with US alone (79.5 % SMG, ► **Fig. 3a–c**).

Extraductal hyperechoic reflexes/calcifications (63.4 % of these were parotid cases, ► **Table 1**) were navigated to/visualized by simUS + SE. In extraductal sialolithiasis the treatment was adapted appropriately (► **Fig. 2a–d**). If an obviously non-sialolithiasis-related unclear extraductal pathology could not be clearly defined, supplemental imaging helped to establish the final diagnosis in 4.05 % of all cases (► **Fig. 1a–c**).

SimUS + SE allowed fast and appropriate management decisions in all patients. In 51.4 % treatment planning and therapy were affected (► **Table 1**, ► **Fig. 4, 5**). It helped to determine whether IDL or ESWL was the most appropriate form of treatment in 29.7 % of the patients (9.5 % PG, 20.2 % SMG) and helped to tailor the treatment to any individual situation – promoting strategic selection of treatment options and improving overall success rates [27]. It was useful to select parotid stones that were not adequately accessible or were inaccessible with SE for treatment by a combined approach (20.3 % of the patients). If the stone was not accessible on SE and the distance was small (< 5 mm), or instruments were at least in contact with the stone when simUS + SE was performed, the combined approach, if necessary with extended sialodochotomy, was considered to be possible without the greater risk of having to decide in favor of parotidectomy intraoperatively (► **Fig. 4a–c**).

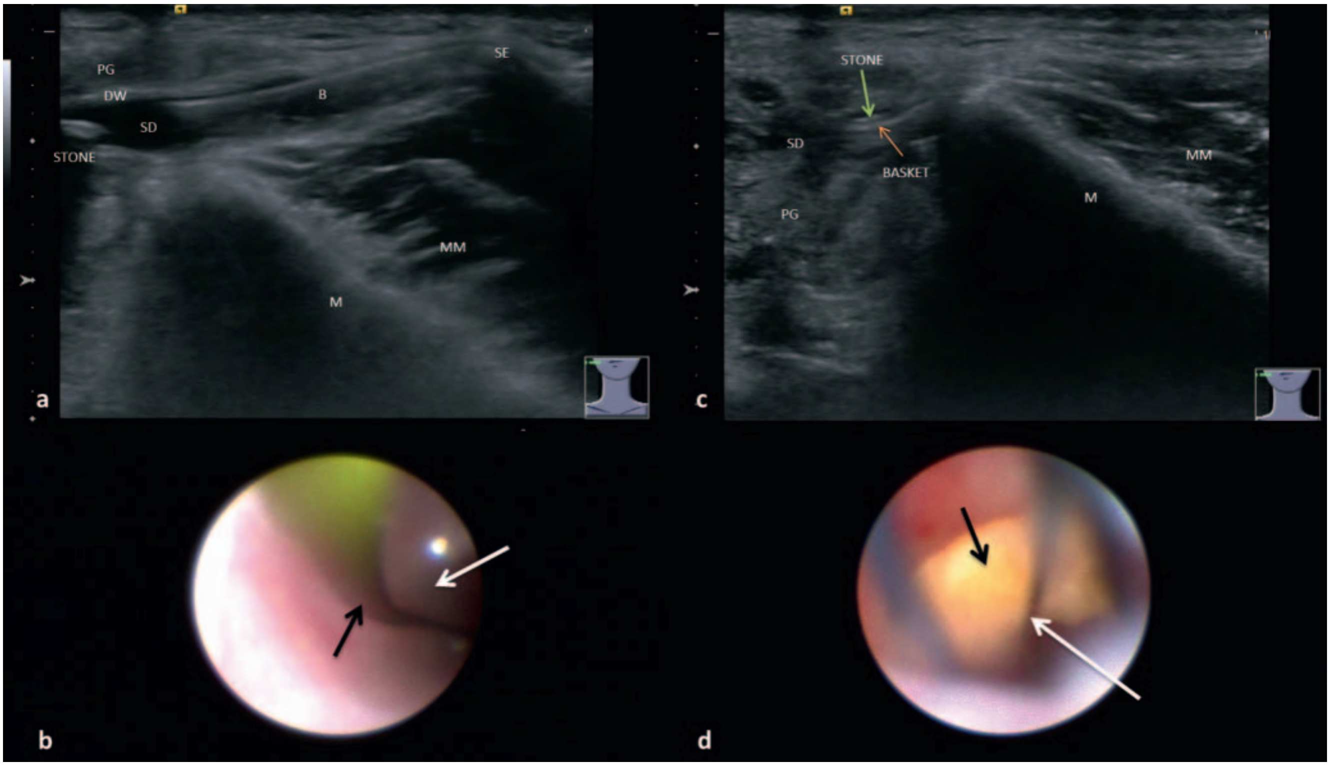
SE-controlled and US-guided stone extraction provides a new option for extracting stones that are not accessible with SE alone. In selected cases, simUS + SE can be used to perform US and SE-guided stone extraction, which was successfully performed in two cases. The PG appears to be better suited for this technique, due to the favorable anatomy of the duct system. This may represent a further advance in comparison with US-guided mechanical stone extraction with instruments such as forceps, as described above [28], as it extends the technical armamentarium of interventional SE [23–27].

With regard to sialolithiasis, findings with various imaging methods, including US, were compared with findings obtained by subsequent SE in order to increase the diagnostic sensitivity and specificity, with the highest values being found after the use of SE, due to the direct viewing of the duct system [1, 3, 14, 16, 17, 21, 29, 30]. With direct intraductal viewing and delineation of extraductal structures, including the parenchyma, simUS + SE provides complete three-dimensional real-time exposure of salivary gland tissue. Video documentation makes it possible to review and reevaluate all findings. This combination of dynamic examinations is at least minimally invasive, or may be completely noninvasive, does not involve any radiation exposure and can be performed as often as needed (by the treating physician).

One important limiting factor with regard to successful application of simUS + SE is that the physicians need to have experience and skills in US and SE and must be ready to perform both examinations in a unit in which both techniques are available in routine practice. This is one possible cause why simUS + SE is described for the first time as a new technique. After adaption by more colleagues, the examiner dependence and interrater reliability of simUS + SE is a possible future research topic.

Conclusion

Simultaneous ultrasound and sialendoscopy is a new approach for patients with sialolithiasis that has proved to be useful for estab-



▶ **Fig. 5 a–d** Simultaneous ultrasound and sialendoscopy (simUS + SE): the US view shows the sialendoscope and an instrument advanced as far as the hyperechoic reflex within the proximal duct system (a stone measuring 2.7 mm, **a**), which was not accessible with the SE. The corresponding sialendoscopic view shows the basket (white arrow, b) advanced into the proximal duct (black arrow, **b**), without a visible stone. After the stone has been captured, the US view shows the basket (orange arrow) with the stone inside it (green arrow, **c**), along with the corresponding sialendoscopic view (basket, white arrow and stone, black arrow, **d**) while the stone was removed. PG: parotid gland; SD: Stensen's duct; DW: duct wall; MM: masseter muscle; M: mandible, SE: sialendoscope; B: basket.

lishing an accurate diagnosis or DD, for preparing and performing the treatment, and for carrying out effective post-treatment follow-up. Diagnostic findings obtained by simUS + SE often were a precondition for performing subsequent treatment measures. This is underscored by the observation that simUS + SE was applied for both diagnostic and therapeutic indications in 20.3 % of the cases. The results presented here suggest that simUS + SE has the potential to improve the management of sialolithiasis.

Conflict of Interest

The authors declare that they have no conflict of interest.

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