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Nasolacrimal duct stenosis—Surgery with a novel robotic endoscope positioning system

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Abstract

Background: Distal nasolacrimal duct stenosis is usually treated by head and neck surgeons with transnasal endoscopic dacryocystorhinostomy (DCR). The presented clinical study discusses advantages and drawbacks of a robot-assisted endoscope positioning system, which allows for hands-free visualization of the surgical field.

Material and Methods: Two patients were treated by surgical DCR. The endoscopic positioning system (Medineering®) features a mechatronic holding arm with four segments and seven degrees of freedom. It is driven by using a foot pedal.

Results: Visualization and instrumentation of the surgical field including the relevant anatomical landmarks were feasible. The endoscope position could be controlled with sufficient precision. The surgeon was able to maintain bimanual instrumentation.

Conclusion: The endoscope positioning system allows for two-handed surgery, which facilitates the essential steps of the surgical procedure. If the benefit of the system is sufficient for the use in clinical routine, it has to be evaluated in repeated applications.

KEYWORDS
dacryocystorhinostomy, endonasal, endoscopic, nasolacrimal duct, robotic, surgery

1 | INTRODUCTION

Nasolacrimal duct stenosis is a pathology, which usually presents with epiphora.[1,2] While it is not a life-threatening disease, patients still suffer from functional issues and a reduced quality of life. Patients also report blurred vision, crusty discharge or recurrent dacryocystitis resulting in mucoceles of the lacrimal sac or the development of fistula through the skin.[3]

The obstruction of the nasolacrimal duct is usually distinguished in subgroups, based on the location of the stenosis, for example, proximal, intra or distal to the lacrimal sac. While a proximal stenosis is commonly treated by ophthalmologists, head and neck surgeons typically focus on the treatment of the stenosis distal to the lacrimal sac. The most common reason for this disease is chronical inflammation of the mucosal tissue, resulting in a progressive fibrosis of the surrounding tissue and therefore, narrowing

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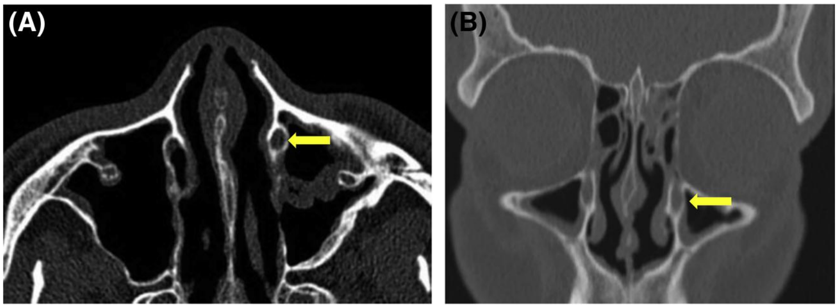

FIGURE 1 Computer tomography (CT) of a patient with nasolacrimal duct stenosis. (A) Axial plane and (B) coronal plane of the CT images show the nasolacrimal duct obstructed by soft tissue on the left side (arrows)

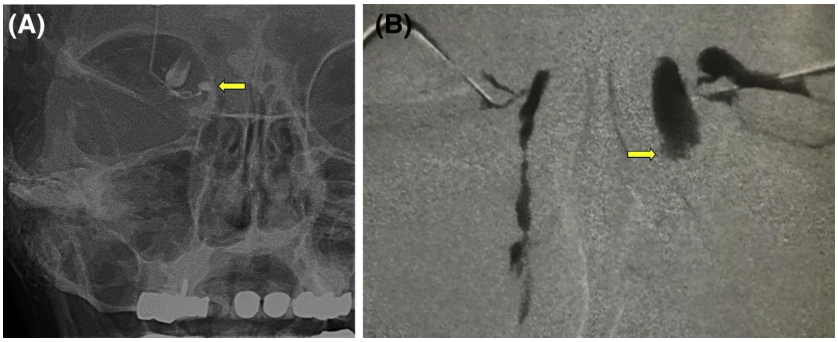

FIGURE 2 (A) Dacryocystography of a patient with stenosis of the proximal lacrimal sac on the right side (arrow). (B) Digital subtraction dacryocystography (DS DCG) of a patient with post-saccal nasolacrimal duct stenosis of the left side. The DS DCG shows a stenosis of the proximal nasolacrimal duct (arrow) and reflux of iodinated contrast material to the conjunctival sac. The right side shows a duct without pathology

of the nasolacrimal duct lumen (Figure 1). Other reasons for developing a stenosis include tumours and traumatic occurrences. The diagnostic roll-up starts with an ophthalmologic examination and the dacryocystography, which can help to distinguish the location of a stenosis, proximal, inside (Figure 2A) or distal to the lacrimal sac (Figure 2B). In case of a distal stenosis, an endonasal examination is compulsory to exclude anatomical or functional obstacles inside of the nasal cavity.[2-5]

The dacryocystorhinostomy (DCR) is performed in case of a distal or common duct stenosis. This surgical procedure allows for an alternative drainage of tear fluid by creating a direct passage from the nasolacrimal sac into the middle nasal meatus, bypassing the nasolacrimal duct. This procedure can be performed using an external or an endonasal approach. The external DCR includes the following steps: (I) creation of an approximately 15 mm straight incision beginning just above the medial canthal tendon reaching down towards the crista lacrimalis anterior, (II) removal of the medial canthal ligament and lateralization of the lacrimal sac, (III) removal of the bone of the lacrimal fossa through an osteotomy, while preserving the nasal mucosa, (IV) vertical incision of the nasolacrimal sac and the nasal mucosa to create posterior and anterior flaps and (V) suture of the flaps creating a pathway from the lacrimal sac directly to the nasal cavity.[6,7] The endonasal approach became popular when the endoscopic technique for the DCR was first described in 1989, which allowed better access to the nasal cavity than the conventional endonasal non-endoscopic DCR.[8,9] The standard endoscopic DCR is performed by using endoscopic sinus surgery instruments and a standard 4mm rigid 0° endoscope and includes the following steps: (I) transnasal preparation of the nasal mucosa over the lacrimal bone, (II) transnasal opening of the lacrimal bone with the chisel or drill, (III) dilatation of the lacrimal canaliculi and introduction of metal probes, (IV) transnasal incision of the lacrimal sac with the knife and (V) pull through of silicone probes into the nasal cavity and fixation with clips or sutures.[10] The silicone probes usually remain in the nasolacrimal duct for 12 weeks.

Advantages of the endoscopic technique include less morbidity, less bleeding and a shorter surgery time in comparison to the external approach.[9] With regard to the cosmetic result, especially in younger patients, the endonasal approach is preferred due to the lack of a visible scar. Furthermore, the pump function of the orbicularis oculi muscle is usually preserved by obtaining the medial canthal ligaments. However, the endoscopic DCR shows some limitations. Acquisition of the endoscopic equipment is considerably more expensive than the equipment required for the external technique. The endoscopic procedure is more difficult to learn, and outcome and success rate of the surgery depend largely on the experience of the surgeon.[9,11,12]

However, considering the advantages of an endoscopic technique, various approaches to enhance the anatomical and functional success rates have been pursued.[4,5] Some authors suggest the use of a silicone tube intubation of the recreated nasolacrimal pathway,[13,14] the application of mitomycin C[15] or an endoscopic nasal cleansing.[16]

The endoscope positioning system by Medineering, previously described by our working group,[17,18] allows for hands-free visualization of the surgical field in the nasal cavity. Compared to standard endoscopic surgery, the surgeon is able to use the surgical instruments with both hands, while the endoscope is guided by the device. The presented clinical study discusses advantages and drawbacks of the surgical positioning tool in the setting of DCR surgery.

2 | MATERIAL AND METHODS

The setup of the endoscopic system has been published before.[17] It consists of a mechatronic holding arm with four segments and seven degrees of freedom (Figure 3A). It is driven by the surgeon using a foot pedal (Figure 3B), and it can be locked in any possible position. The maximum load capacity is 2 kg. Joints of the holding arm are released by touchpads on each segment, and the status of the system (locked/released) is visualized by Light-emitting diode (LED) lights. On its distal end, a compact robotic hand with five actuated degrees of freedom performs the movement of the endoscope, driven by five brushless direct current (DC) motors. Standard 4 mm endoscopes are connected to the robotic hand with a specific clip mechanism. Three-dimensional motion and fine adjustment of the endoscope are controlled by the surgeon through a custom foot pedal with joystick (Steute Inc.). The pedal also allows to home the endoscope to a basic position with an extra button. The surgeon can switch between transitional movement and pivot point rotation of the endoscope. A standard endoscope (Karl Storz) with a view angle of 0° was used and attached to the guiding system with a 4 mm endoscope clip.

The system was used for visualization during the transnasal procedure of a DCR in two patients (37 and 57 years) with a post-saccal stenosis of the nasolacrimal duct (Figure 3C). The surgical setup was identical to the conventional transnasal DCR. The robotic positioning system was fixed to the surgical table. Afterwards, the endoscope was connected using an endoscope clip. The endoscope was then introduced manually and brought in the correct position for surgery. Sterile drapes were used to cover the system during surgery.

3 | RESULTS

Positioning and introduction of the endoscope into the nasal cavity was possible in a reasonable span of time. Visualization and instrumentation of the surgical field were feasible with the presented setup. Controlling the robotic endoscope positioning system was adequately precise. Displacement of the system during surgery could not be detected in spite of instrumentation with conventional force. After manual adjustment of the endoscope to the positioning system, the endoscope position was controlled with sufficient precision by using the foot pedal. This allowed bimanual instrumentation during the surgical procedure (Figure 4A–C). A manual removal of the system during surgery in order to clean or reposition the system was not required.

The endoscope allowed for good visualization of the nasal cavity including the uncinate process, the middle turbinate and the lacrimal bone. The maxillary line was easily identified. Anterior to the uncinate process, the nasal mucosa was incised in a c-shaped manner and lifted off the bone, creating a mucosal flap. The tension on the tissue could be maintained by the second instrument while cutting, which allowed for an easier and more precise incision. The exposed bone of the frontal process of the maxilla and the lacrimal bone were excavated with a chisel. Again, the elevated mucosal tissue could be displaced and secured out of surgical field by the second instrument, allowing for a better view of the operation site and simultaneously, protecting the mucosal flap. The lacrimal sac was displayed by inserting a probe through the upper canaliculus. The lacrimal sac was opened using a sickle knife. The bimanual instrumentation allowed the surgeon a better exploration of the surgical field with less traumatization of the tissue during preparation. This is likely to reduce the risk of damaging the lateral wall of the lacrimal sac, which could cause scarring and poor post-operative canalicular function.[19] The metal probe was relocated into the nasal cavity and secured using clips and knots, which were easily tied using a bimanual instrumentation. The manual removal of the system at the end of the surgery required merely a few seconds. The robotic endoscope guiding system proved to be beneficial for all transnasal steps of the procedure, as two-handed surgery enabled the surgeon to better manipulate the tissue (Figure 4).[20] In both cases, there were no complications during or after the surgery. In the follow-up treatment, both patients showed no signs of epiphora.

4 | DISCUSSION

Using a robotic endoscope positioning system for transnasal surgery of the nasolacrimal duct can be beneficial for surgeons and patients in a clinical setting. The surgical field in the nasal cavity is limited in size and easy to reach with the endoscopic system. The presented positioning system allows for bimanual instrumentation and intuitive handling. This may result in shorter operating times and better clinical outcomes. On the other hand, the setup time of the endoscopic system has to be considered in the evaluation of the total time of the surgical procedure.

Another possibility to perform bimanual instrumentation is a four-handed approach with one main surgeon and one assistant surgeon to guide the endoscope. However, space limitations impede the movement of instruments at the level of the nostrils. Additionally, four-handed surgery is not always possible due to the limited availability of staff. Using the described guiding system, an additional assistant is not needed.[21]

Drawbacks of the study include that the system does not contain an irrigation system in the presented setup, which might make it necessary to occasionally remove the positioning system from the operative field, due to fogging and staining, as previously

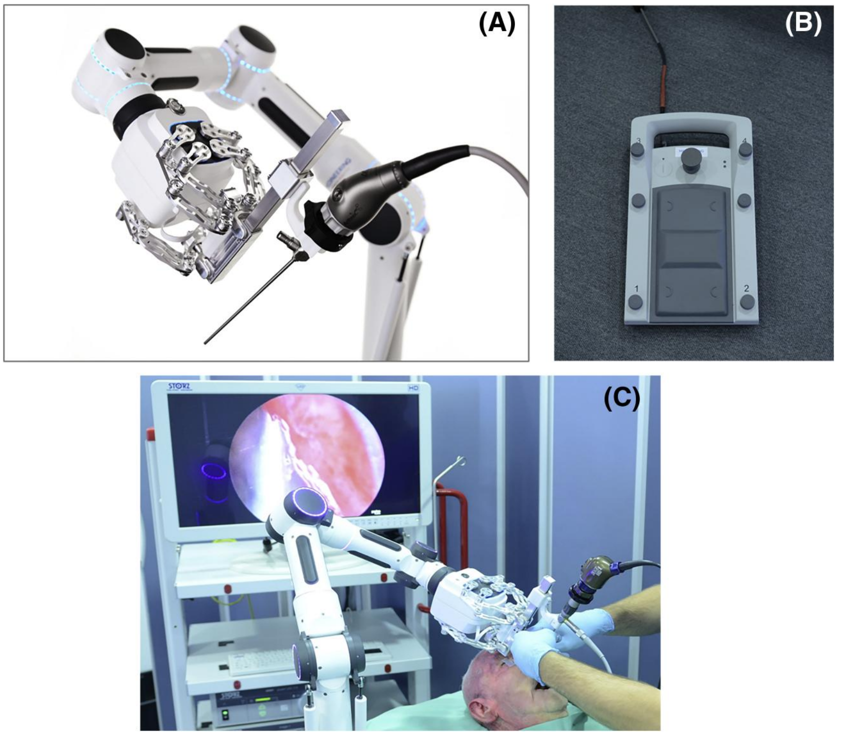

FIGURE 3 (A) Overview of the endoscopic positioning system. (B) Foot paddle used for steering the endoscopic positioning system. (C) Setup of the system for two-handed transnasal surgery

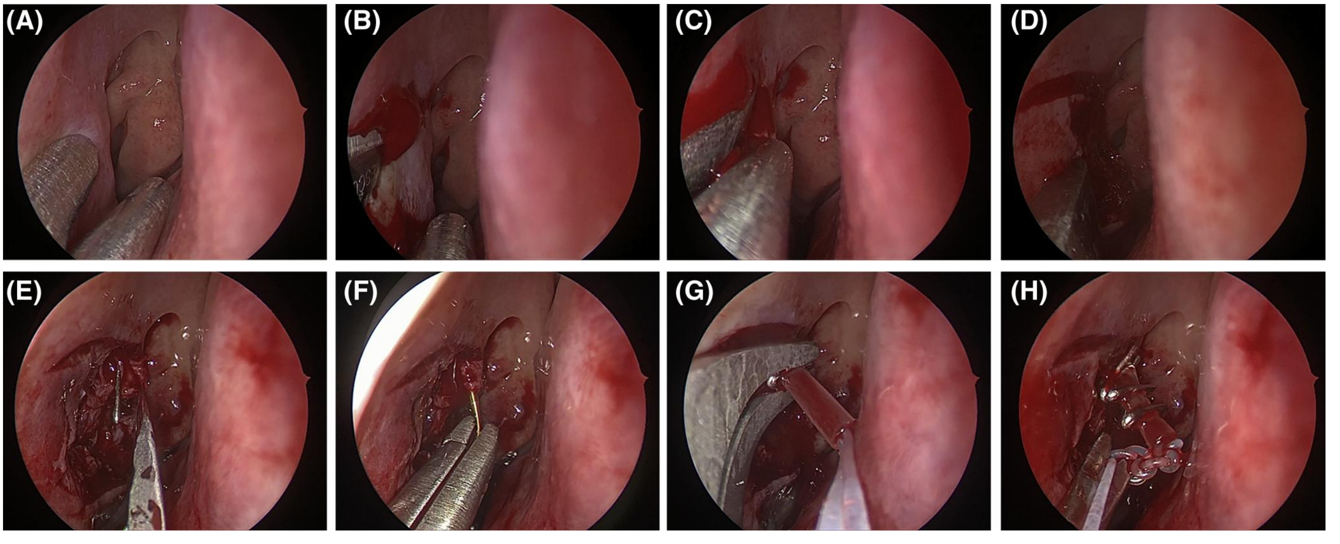

FIGURE 4 Steps of the surgical procedure. (A) Visualization of the maxillary line with freer-elevator and suction tube, (B) lifting of nasal mucosa, (C) preparation of the mucosal flap with freer-elevator and suction tube, (D) opening of the lacrimal bone with chisel, (E) opening the lacrimal sac, (F) relocating the metal probe into the nasal cavity and (G + H) fixing the probes with clips and knots

described. However, in our clinical setting, this was not necessary. The positioning system can be combined with an endoscope with changeable view angles. In this case, it would be beneficial if the viewing angle of the endoscope could be manipulated by the foot pedal. However, if a rigid endoscope without alterable view angles is used, the angle can only be changed manually through installing a different endoscope to the system.[17] Additionally, visualizing the uncinate process required a longer time with the endoscope holder system than with standard endoscopic DCR. At times, the positioning process was difficult and time consuming due to the limited size of the nasal cavity. Obviously, the number of patients was limited. However, at the current stage, no further knowledge would be obtained by additional patients.

Interference of the endoscopic positioning system and instruments in this context has previously been described as a common problem in other locations, for example, the skull base.[22] But, as the nasal cavity has a large diameter in the proximity of the lacrimal bone, there was no interference in the presented setup. Further miniaturization of the system should be pursued, in order to increase the list of indications, for example, surgical procedures of paranasal sinuses as well as the anterior skull base.

5 | CONCLUSION

Using a robotic endoscope positioning system for transnasal surgery of the nasolacrimal duct allows for two-handed surgery, which facilitates the essential steps of the surgical procedure. If the benefit of the system is sufficient for the use in clinical routine, it has to be evaluated in repeated applications.

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CONFLICT OF INTEREST

The authors declare that they have no financial disclosures and that they have no economic interests in the presented system.

AUTHOR CONTRIBUTIONS

Felix Boehm analysed the results and wrote the paper, Fabian Sommer treated patients, Daniel Friedrich organized system setup, Jens Greve created figures, Marc-Oliver Scheithauer edited manuscript, Thomas Karl Hoffmann designed the research and edited manuscript and Patrick Johannes Schuler designed the research and treated patients. All authors have revised and approved the manuscript.

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