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Technical Notes & Surgical Techniques

VITOM®-3D in lumbar disc herniation: Preliminary experience

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ABSTRACT

Objectives: In neurosurgery, optimal illumination and surgeon view's magnification are essential to perform delicate and dangerous operations, such as aneurysms clipping and tumors removal. In this paper, the authors report their initial experience using a 3D-exoscope in spinal surgical procedures.

Patients and methods: From January to July 2018 we performed 9 lumbar discectomies using a VITOM®-3D exoscope. We decided to examine these cases, with particular attention to the surgical timing and to the postoperative results in terms of pain control (VAS). Patient positioning, surgical instruments and approach technique were essentially the same used routinely in standard spinal disc herniation surgery.

A "control" group composed of 9 cases was selected from patients who underwent a standard discectomy during the same period with the same neurosurgeons in order to obtain two homogeneous and comparable populations.

Results: The length of operative time was measured and appeared to be longer in exoscope-assisted discectomies than in the traditional procedures (average 160 min vs 133 min); moreover the one-month postoperative VAS of the two groups were collected and compared but, after a statistical analysis, these differences resulted to be not statistically significant. No technical difficulties or surgical complications were noted.

Conclusions: Despite the limited group of patients, the VITOM®-3D exoscope can be considered an interesting instrument in spinal procedures. It cannot permanently substitute the operating microscope but it shows interesting characteristics that make it a useful tool for surgeon's comfort and a versatile and relatively economic instrument in the neurosurgical armamentarium, as a part of a 3D working station composed by endoscope and exoscope.

1. Introduction

In neurosurgical environment, excellent visualization and illumination are essential to perform any kind of procedure safely and successfully. Since the beginning of the technological era, multiple attempts were made to improve and magnify the surgeon's view. A revolutionary innovation was the operating microscope, introduced by Yasargil in the 1970s [1], for management of intracranial pathologies, which quickly became one of the most important tools of the neurosurgical armamentarium. After few years Wolfhard Caspar demonstrated the microscope usefulness also for spinal surgery [2].

From that moment onwards, the operating microscope has offered the surgeon a binocular system with a magnified and tridimensional view of the surgical field, and the chance to adjust the focal length, the magnification and the brightness by an electrical drive. Despite all these advantages, microsurgery still shows some weak points. Its principal downside is its large size and a remarkable cost. Furthermore the limited maneuverability and the uncomfortable positions that the surgeon and his assistant need to assume in some kind of operations, can influence surgeon's concentration level, efficiency and the surgical management of the procedure [3].

In the last decades, other visualization techniques have been developed. Nowadays endoscopic procedures are widely accepted in cranial and in spinal neurosurgery. The endoscope offers an extremely short viewing distance on the surgical target and allows to achieve the goal with a minimally invasive and mostly atraumatic approach. Furthermore, surgical images are visualized on a screen, which permits a more natural and comfortable positioning for the surgeon and his team. On the other side the major limitations of this technique have been the bidimensional surgical view, the extremely restricted working space.

In order to overtake these limits and to allow the surgeon to move

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more freely, the exoscopic telescope has been introduced in the surgical practice. It presents a longer focal distance and offers a wider view and working spaces. It can be positioned 20 cm or even farther above the surgical field. It is not large as a microscope and has a wide maneuverability [3], offering the surgeons a more comfortable working space and more flexibility on focusing the surgical target.

In this paper, we report our initial experience using a 3D-exoscope in lumbar discectomies: the surgical duration of standard discectomies to the exoscope-assisted discectomies and the postoperative results in terms of pain control (VAS) have been compared in order to evaluate the VITOM®-3D not only as a more comfortable tool for the neurosurgeon, but also as an useful instrument for the management of spinal pathologies.

2. Patients and methods

2.1. Patients selection

From January to July 2018 we performed 9 lumbar discectomies using a VITOM®-3D exoscope (Karl Storz GmbH, Tuttlingen, Germany). Despite the limited number of patients we decided to examine these cases with particular attention to the surgical timing and to the postoperative results in terms of pain control (VAS). This group of patients was composed by 4 males and 5 females. In 5 cases the surgical level was L4-L5 and in 4 cases L5-S1. A “control” group of 9 patients who underwent a standard lumbar discectomy was selected to obtain two homogeneous and comparable populations for herniation level and surgical treatment. The control group patients were selected from the cases treated by the same neurosurgeon during the same period (from January to July 2018) in our Institution. These ones present the same side and level of lumbar disc herniation of the VITOM®-3D patients. Furthermore, the two groups show similar age and BMI, that are the most influencer of the surgical outcome. Patient characteristics and pathological details are reported in Table 1.

2.2. Surgical technique

All the procedures were performed by two neurosurgeons. Since in spinal surgery the assistant surgeon needs a second “reverse” 3D-monitor, two 3D screens were positioned in front of each surgeon to achieve the best possible comfort (Fig. 1).

The VITOM®-3D system is composed by a mobile holding arm (VERSACRANE™), a 3D EXOSCOPE, and a remote control unit (IMAGE PILOT).

We decided not to have a strict rule in positioning the VERSACRANE™ and the 3D-EXOSCOPE in the operation room. Different variations and multiple combinations are possible indeed. Nevertheless it is pivotal to avoid the interposition of the hand of the first operator between the 3D camera and the surgical field. The holding arm was positioned on the left side of the first surgeon and on the opposite side of the assistant. The distance between the exoscope and the surgical field was decided by the surgeons to allow a comfortable position and to have enough zoom for surgical instruments.

All the patients underwent general anesthesia and were operated in prone position. Surgical level was confirmed by the use of a fluoroscope. After completed the setup of the surgical field, the VITOM®-3D exoscope was dressed by a sterile cover and positioned directly above the surgical field, at 20–50 cm distance.

The neurosurgeons performed a 3 cm skin incision for a posterior interlaminar approach, performing hemilaminectomy and flavotomy; the procedure was then completed with discectomy and foraminotomy on the affected side (Fig. 2) and repositioning of ligamentum flavum to respect the root ecology [4,5].

In every procedure all the members of the operative team wore polarized glasses to visualize the 3D images. The control unit (IMAGE PILOT), dressed by a sterile cover, is usually driven by the assistant neurosurgeon or alternatively controlled by a resident in a not sterile way. It allows one to easily modify zoom and focus, to move the images in a specific range of interest, and to open the navigation menu of the system.

2.3. Statistical analysis

To compare surgical times and postoperative VAS average improvement of the two groups of patients the Mann-Whitney test was employed, which is a non-parametric test with a null hypothesis (H_0): under the null hypothesis, the distributions of both populations are equal and there are no statistically significant differences between the

Table 1
Patients characteristics and surgical details.

A: Standard procedures

Patient	Sex	Age	Level	Procedure	Comorbidity
1	M	43	L4-L5 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
2	M	52	L4-L5 right	Right hemilaminectomy, hemiartectomy and foraminotomy, herniectomy, discectomy	Iatrogenic panhypopituitarism
3	M	52	L4-L5 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
4	F	46	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None
5	F	43	L4-L5 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None
6	F	41	L4-L5 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
7	M	25	L5-S1 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
8	F	21	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None
9	F	60	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	Arterial hypertension

B: VITOM-3D procedures

Patient	Sex	Age	Level	Procedure	Comorbidity
1	M	60	L4-L5 left	Left hemilaminectomy, foraminotomy and hemiartectomy, herniectomy and discectomy	None
2	M	38	L4-L5 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None
3	M	44	L4-L5 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
4	F	48	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	Psoriatic arthritis
5	F	49	L4-L5 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	Allergic asthma, epilepsy
6	F	41	L4-L5 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
7	M	50	L5-S1 left	Left hemilaminectomy, foraminotomy, herniectomy and discectomy	None
8	F	47	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None
9	F	50	L5-S1 right	Right hemilaminectomy, foraminotomy, herniectomy and discectomy	None

Fig. 1. Operating theater setting with the two opposite monitors for each surgeon.

two groups. This test can be used to determine whether two independent samples were selected from populations having or not the same distribution.

3. Results

No technical difficulties or surgical complications related to the use of the exoscope were noted; in no case was necessary to convert the operation in a microscope-assisted procedure and the patients of both groups presented successful clinical outcomes: the preoperative average VAS scores were almost equal in the two groups (6 vs 6.1) and presented a huge improvement in both populations after one month from the surgical treatment (1.6 vs 1.2), with similar average improvements (4,6 vs 4,9) and a nearly complete recovery of the focal neurological deficits at one month postoperative follow-up (Table 2). The average length of operative time was measured and appeared to be longer than the standard procedures: the VITOM®-assisted lumbar discectomy appeared to be longer than a standard lumbar discectomy (160 vs 133 min) (Table 3).

As previously said, the surgical times and the one-month postoperative VAS average improvement of the two groups of patients were statistically analyzed using the Mann-Whitney test, a non-parametric test for independent samples, with null hypothesis (H_0) that there are no statistically significant differences in the two groups. The standardized T value (Z_T) - obtained computing our two samples (-1.19 for surgical times and 0.84 for the postoperative VAS) - were compared with the reference critic value (for a confidence interval $CI < 0.05$) of -1.96 and 1.96. Our results didn't permit to exclude H_0: between the two groups there are minimal differences in the surgical times and in postoperative pain improvement, but these are not statistically relevant.

4. Discussion

The first HD exoscope arrived in the surgical horizon, in order to combine maneuverability to magnified vision [6]. This system was used in different surgical specialties such as OBGYN, ENT, urology, and abdominal surgery [7–11]. Its use in neurosurgical procedures has been attempted but limited [12] until the arrival of the 3D-exoscope. This technique, offering a 3D screen view of the surgical field, permits to all the members of the surgical equipe, if wearing 3D-glasses, to have the same tridimensional and detailed vision of the first operator.

We didn't notice any problems related to the use of these special glasses, which are comfortable, light and also represent an individual protection device. In addition the company offers a pince-nez version that could be worn on traditional glasses without any discomfort.

We noted multiple positive aspects connected with the use of the exoscope. It permits a very gentle and respectful detachment of all the tissue layers as demonstrated in cadaveric studies [13]. Furthermore it offers the possibility to expose neural structures with a high grade of precision and effectiveness. Using this tool, we obtained successful surgical outcomes, with mostly complete recovery of the pain and the neurological deficits (Table 2), without any complication: the results were mostly equal to the ones obtained in patients treated with standard approach. Moreover, as already reported for augmented reality training technologies [14], the exoscope plays a very important role in residents education and formation since they can follow the surgical procedure from the skin incision to the final suture, having the same vision of the first operator.

According to the most recent literature about VITOM®-3D exoscope [6], the surgical times using the VITOM®-3D appeared to be longer than the standard approach. Therefore the postoperative VAS average improvement seemed to be higher in the exoscope group than in the standard discectomy cohort (4,9 VS 4,6). After a statistical analysis of our data with Mann-Whitney test, the differences in the surgical times and postoperative VAS improvement between the two groups resulted to be not statistically relevant. In our opinion this is due to the confidence of our neurosurgical team in performing endoscopic procedures: in fact, we gained immediate confidence with the exoscope, since we are used with the endoscope to perform surgical procedures

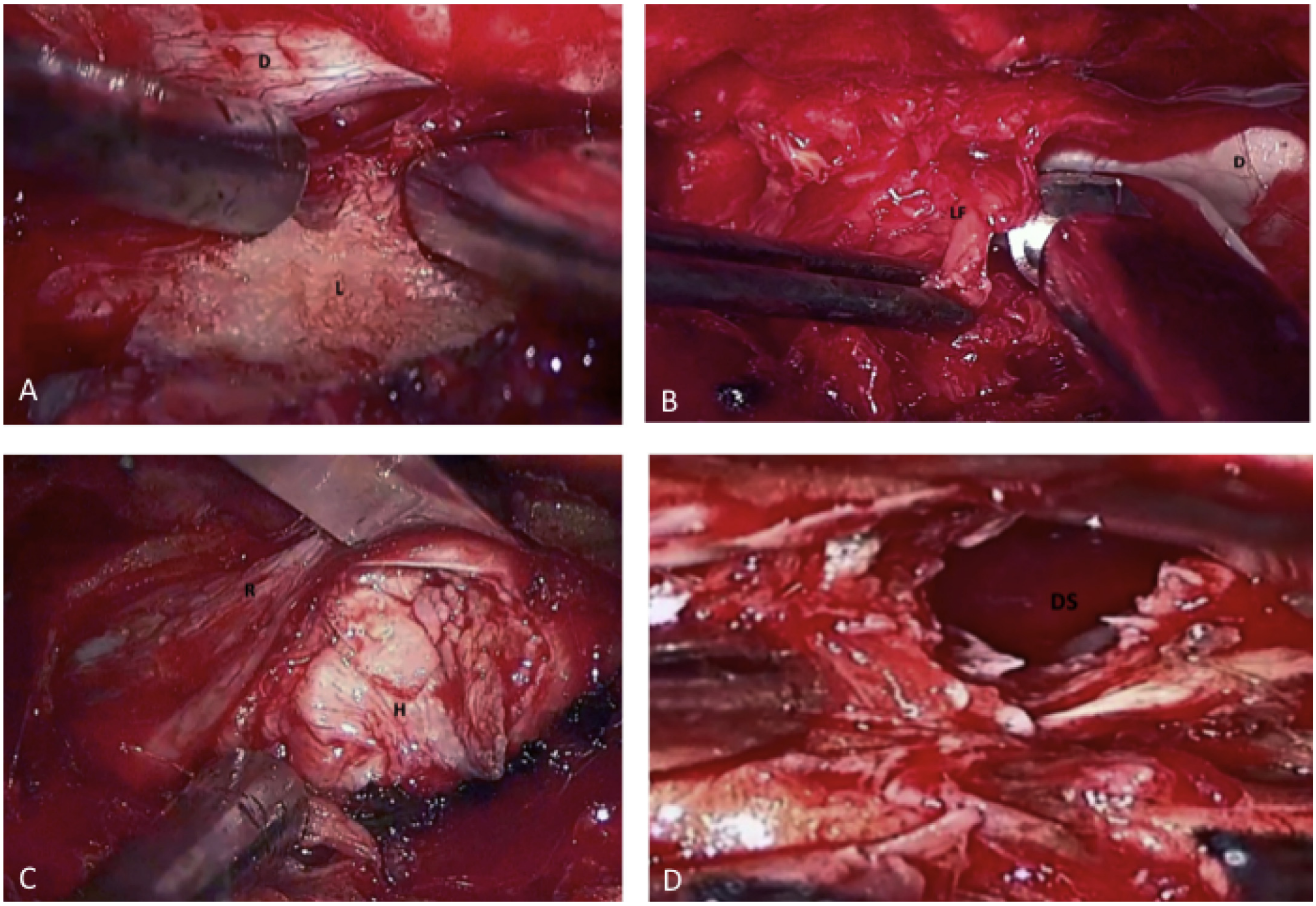

Fig. 2. Intraoperative images:
A) Hemilaminectomy.
B) Flavectomy.
C) Herniectomy and discectomy.
D) Final check of the discal space.
L: lamina; LF: ligamentum flavum; R: nerve root; D: dural sac; DS: discal space; H: hernia.

watching on a screen, with a high grade of precision and effectiveness.

We experienced that this system has multiple potential technical aspects in spinal neurosurgery, in terms of optics and maneuverability. It permits, with an high grade of maneuverability, to improve the visualization of surgical corridors through its innovations in illumination, magnification and 3D view: in our series, both standard and exoscopic approach offered satisfying and comparable results in terms of post-operative neurological recovery and VAS improvement; moreover it has the potential to be used in the neurosurgical training of residents and young specialists [15]. On the other hand we noted that the exoscope does not permit to achieve very angulated vision trajectories, in comparison with the operating microscope, because only a perpendicular position above the surgical field authorizes to obtain a focused image [16].

By a self-critique point of view, focusing on the strengths and weaknesses of our study and how may influence the validity and robustness of the findings, the choice of a standard technique always represented a certainty of effectiveness and safeness, allowing the direct visualization of all the structures and tissue layers with a 3 cm skin incision; the complication rate is very low and usually patients are discharged on postoperative day 1.

Secondly the long operative times are partially due to: the use of the fluoroscope that has to be carried and shared with all the operating rooms, the action time of the antibiotic irrigation in the discectomy site and the anesthetic subcutaneous infiltration of the wound which is done before the final closure and decided together with the anesthesiologist; usually these activities take at least 30 min during a surgery.

At our knowledge this is the first case-control comparison of the operative times and postoperative in patients treated with a standard discectomy and cases operated with the exoscope.

Further studies are necessary to improve and confirm the use of the exoscope in spinal surgery.

5. Conclusions

Despite the limited group of patients, the VITOM®-3D exoscope can be considered an interesting instrument in spinal procedures. It cannot permanently substitute the operating microscope but it shows interesting characteristics that make it a useful tool for surgeon's comfort and allows a simple surgical management of the patient. In the author's opinion, the 3D exoscope represents a versatile and relatively economic instrument in the neurosurgical armamentarium, as a part of a 3D working station composed by endoscope and exoscope.

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Table 2
Pre and post-operative vas and neurological examination.

A. Standard procedures

Patient	Level	Pre-OP VAS	Pre-OP NE	Post-OP VAS	Post-OP NE
1	L4-L5 left	6	Left lower limb hypoesthesia	2	None
2	L4-L5 right	8	Left thigh hypoesthesia	3	None
3	L4-L5 left	5	Left foot hypoesthesia	2	None
4	L5-S1 right	5	Reduction of right foot dorsiflexion (3/5)	2	None
5	L4-L5 right	5	Right leg and foot hypoesthesia	1	None
6	L4-L5 left	6	Reduction of left leg flexion (3/5) and hypoesthesia	1	None
7	L5-S1 left	5	Left lower limb hyporeflexia	0	None
8	L5-S1 right	8	Reduction of right foot dorsiflexion (3/5) and plantar flexion (4/5) with right leg and foot hypoesthesia	2	Reduction of right foot dorsiflexion (4/5)
9	L5-S1 right	6	Right leg and foot hypoesthesia	2	None
Average		6		1,66666666	

B. VITOM 3D procedures

Patient	Level	Pre-OP VAS	Pre-OP NE	Post-OP VAS	Post-OP NE
1	L4-L5 left	8	Reduction of dorsal and plantar flexion of left foot (2/5) and left lower limb hypoesthesia	2	Reduction of left foot dorsal flexion (4/5)
2	L4-L5 right	5	Right lower limb hyporeflexia	0	None
3	L4-L5 left	5	Left patellar hyporeflexy, left thigh, leg and foot hypoesthesia	2	None
4	L5-S1 right	6	Right thigh, leg and foot hypoesthesia	0	None
5	L4-L5 right	6	Reduction of right foot big toe extension (3/5) and right lower limb hypoesthesia	1	Reduction of right foot big toe extension (4/5)
6	L4-L5 left	6	Left leg and foot hypoesthesia	2	None
7	L5-S1 left	8	Reduction of left foot dorsiflexion (3/5), left patellar hyporeflexy and left leg and foot hypoesthesia	2	None
8	L5-S1 right	6	Right patellar and Achilles hyporeflexia	2	None
9	L5-S1 right	5	Right of right foot plantar flexion (4/5), right leg and foot hypoesthesia	0	
Average		6,111111111		1,222222222	

Table 3
Surgical times computing.

Standard procedures			VITOM®-3D procedures		
Patient	Level	Time (min)	Patient	Level	Time (min)
1	L4-L5 left	145	1	L4-L5 left	180
2	L4-L5 right	95	2	L4-L5 right	160
3	L4-L5 left	100	3	L4-L5 left	210
4	L5-S1 right	100	4	L5-S1 right	120
5	L4-L5 right	155	5	L4-L5 right	195
6	L4-L5 left	130	6	L4-L5 left	135
7	L5-S1 left	100	7	L5-S1 left	135
8	L5-S1 right	195	8	L5-S1 right	130
9	L5-S1 right	180	9	L5-S1 right	175
Average		133,3333333			160

Declaration of competing interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.inat.2019.100547.

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