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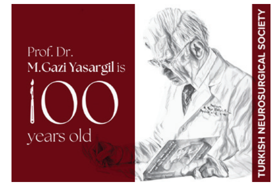

Original Investigation
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Is There Postoperative Fluid Accumulation After the Unilateral Biportal Endoscopic Technique as Minimally Invasive Spine Surgery: In Vivo Study

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ABSTRACT

AIM: To establish the presence and amount of fluid accumulation in UBE procedure, and the relationship of fluid management with other variables.

MATERIAL and METHODS: All patients underwent UBE spinal surgery with one level between September 2019 and February 2022. The exclusion criteria were determined. All early MRI-STIR images from all patients up to the 12th-h postoperatively were collected. All MRI STIR images were evaluated by matrix laboratory (MATLAB) for fluid accumulation. Statistical analysis was done by SPSS 22.0 (IBM, Armonk, NY).

RESULTS: The hospital archive records of 39 patients were assessed in this study. The mean matrix laboratory measurements (cm3) for women was 58.75 ± 18.870 and that for men was 49.86 ± 18.977. No significant difference was found in terms of gender in matrix laboratory value (p=0.161). Matrix laboratory value was negatively correlated with height but positively correlated with BMI and the subcutaneous adipose tissues. There was no significant difference between the genders in terms of age, BMI, and matrix laboratory.

CONCLUSION: Any complications of fluid accumulation in the UBE study group were not detected. The fluid accumulation in UBE was within physiological limits. Matrix laboratory is a good and applicable method for spine surgery.

KEYWORDS: Spine surgery, Minimally invasive, Unilateral biportal endocopy (UBE), Fluid leakage

ABBREVIATIONS: UBE: Unilateral biportal endocopy, **BMI:** Body mass index, **ALL:** Anterior longitudinal ligament, **MATLAB:** Matrix laboratory

INTRODUCTION

Unilateral biportal endoscopy (UBE) is one of the popular minimally invasive approach preferred in spine surgery. Its advantages include protection of the multifidus muscles, facet joint and facet joint capsules, effective decompression for the 4 nerve roots in the same segment with two small incisions, shorter hospital stays, and less amount of back pain during the postoperative period (10,14). UBE include endoscopic and working portals in the

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pleonasm that provide a clear operation field (16). UBE has a protective surgical technique because of using intermuscular spaces of multifidus muscle (1,3). The approach to success in the UBE procedure is influenced by the extent of understanding about the fluid dynamics during the operation. In addition, UBE maintains stable water dynamics in the operation field. The sufficient flow in and out of the fluid into the operation field is the best approach for the successful management. A study recommended water pressure <30 mmHg during the UBE procedure for expert supervision (10). However, the ideal water pressure has not yet been established in the literature. Hong et al. established an ideal range of water pressure by measuring the mean water pressure in UBE (7). Hong et al. advised the laws of Bernoulli's equation and Pascal's for this procedure. Other factor affecting the water dynamics include the difference in height, mass resistance, and injection pressure (7). Continuous fluid (saline) flow provides clear endoscopic visualization and prevent infection and radiofrequency (RF) electrode thermal effects. Fluid circulation also provide clear visualization by by clearing the debris from the operating field. Moreover, hydrostatic pressure can stop the bleeding by balancing the blood pressure in the operative field. Low blood pressure can help in operation cases in a low hydrostatic pressure medium. Low hydrostatic pressure is important for preventing fluid accumulation from the operation field into the surrounding tissues. However, under high blood pressure environments, the fluid pressure cannot balance the bleeding with low or acceptable hydrostatic pressure. Thus, it can cause fluid accumulation into the surrounding tissues, which results in muscle edema and ascites, especially after surgery (6,12,17). On the other hand, fluid medium can improve wound healing and prevent infections and can reduce some complications such as dura or nerve root injury.

This study aimed to determine the mean amount of fluid accumulation into the surrounding soft tissues in each UBE procedure. Also, the relationship and boundaries of this fluid accumulation with the muscle compartments and connective tissues were researched. The relationship of fluid management with other variables and water dynamics are remained under investigation.

MATERIAL and METHODS

This was a retrospective, multi-disciplinary, in vivo study on the UBE procedure. The institutional ethical approval form was obtained for our study design, and we registered the clinical trial dated 09.09.2022. We recorded all patients who underwent UBE spinal surgery with one level between September 2019 and February 2022. The written informed consent was obtained from all patients. One level paramedian UBE surgery cases were included the study. The exclusion criteria were as follows: i) spinal revision surgery or instrumented patients, ii) intraspinal malignancies (1), iii) spinal infections (7), iv) multilevel UBE procedures, and v) paravertebral approaches. The demographic characteristics were determined as gender, age, weight, height, body mass index (BMI), and preoperative medical condition (judged using the American Society of Anesthesia Physical Status). Moreover, the subcutaneous adipose tissue values were measured for all patients in accordance with the study by Lee et al. (13).

Study Design

Intraoperative semi-tubular retractor was employed in all patients who underwent UBE surgery. The height of the fluid used was kept 28 cm (20.59 mmHg) above the patient's bed level; this height was kept constant for each patient. In addition, each patient was operated at a fixed height of 72 cm from the floor. All early MRI-STIR images from all patients up to the 12th-h postoperatively were collected. In the MRI-STIR images, anatomical operation field was categorized into 4 compartments to observe the fluid accumulation during the UBE procedure. The anterior segment of the anterior longitudinal ligament (ALL) was termed the 1st compartment (k1); the segment between ALL and ligamentum flavum as the 2nd compartment (k2); the segment between ligamentum flavum and subcutaneous fascia as the 3rd compartment (k3); and the segment between ligamentum fascia of the back muscles and skin as the 4th compartment (k4) (Figure 1).

Matrix Laboratory (MATLAB) Studies

The term MATLAB (1194, The MathWorks, Inc., LV, USA) as a standard means "MATrix LABoratory" which is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. In this study, a method was adopted to objectively measure the size of the edematous areas on the MRI STIR images of lumbar vertebrae. In this method, the edema area with the highest fluid density was determined in 3 consecutive MR sections using matrix laboratory (GE MEDICAL SYSTEMS SIGNA Explorer, USA). Then, 1.5 Tesla was applied in the experiments, and the scanning parameters were as follows: Segment: Vertebra,

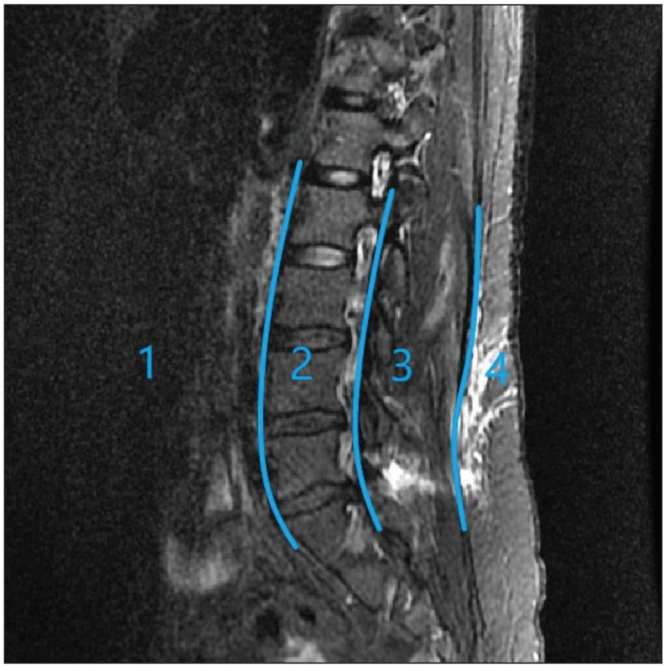

Figure 1: Categorized 4 compartments to observe the fluid accumulation during the UBE procedure.

Sequence STIR, Plane: Sagittal, Acquisition Matrix: 512x512, Pixel Spacing: 0.55–0.55 mm, Slice Thickness: 4.5 mm, Spacing Between Slices: 5.5 mm. To determine the size of the edema area, an algorithm was developed.

Statistical Analysis

SPSS 22.0 (IBM, Armonk, NY) program was applied for data analysis. Normality test of numerical data was conducted with the Kolmogorov–Smirnov test and normal distribution was determined. The t-test was used to compare the dependent variable according to the categorical data. Pearson's correlational test was used to analyze the relationship between numerical data. Cohen's kappa was used to examine the reliability of qualitative data. Inter- and intra-observer measurements were conducted statistically. $p<0.05$ was considered to indicate statistical significance.

Table I: Some Data of the Patients Included in the Study

	Mean	Std. Deviation
Age (years)	50.44	14.968
Height (cm)	167.26	9.069
Weight (kg)	78.28	11.562
BMI (Body Mass Index) (kg/m^2)	27.97	3.3638
Subcutaneous Adipose Tissue (mm)	26.50	8.286
MATLAB (cm^3)	53.05	18.870
Male: 25 (64.1%) Female: 35.9 (35.9%)		
Total patients (n=39)		

RESULTS

The hospital archive records of 39 patients were assessed in this study. All patients met the inclusion criteria. The demographic, anthropometric, and clinical details are depicted in Table I. The mean age of the patients included in the study was 50.44 ± 14.968 years, and they included 25 (64.1%) men and 14 (35.9%) women (Table I). The first and second measurements and the 2 radiologists' compartment fluid status are shown in Table II. In the follow-up of the study group, fluid accumulation cause some complications as subcutaneous edema, ascites, or cellulitis.

The mean matrix laboratory measurements (cm^3) for women were 58.75 ± 18.870 and that for men were 49.86 ± 18.977. No significant difference was found in terms of gender in matrix laboratory value (p=0.161). Matrix laboratory value was negatively correlated with height, but positively correlated with BMI and the subcutaneous adipose tissues (Table III). In the 1st and 2nd evaluations of all compartments in terms of fluid, a statistically significant difference and significant agreement were recorded between the two radiologists (Table IV). Cohen's Kappa was used to examine the reliability of the qualitative data. Matrix laboratory sample figures are shown in Figure 2. There was no significant difference between the genders in terms of age, BMI, and matrix laboratory (Figures 3 and 4). A comparison of matrix laboratory, age, and BMI is shown in Table V.

Table II: First and Second Measurements and 2 Radiologists Compartment Fluid Status

		R1				R2			
		Measurement		Measurement		Measurement		Measurement	
k	fluid	n	%	n	%	n	%	n	%
k1	Absent	39	100.0	39	100.0	39	100.0	39	100.0
	Presence	Null	0.0	Null	0.0	Null	0.0	Null	0.0
k2	Absent	10	25.6	8	20.5	8	20.5	6	15.4
	Presence	29	74.4	31	79.5	31	79.5	33	84.6
k3	Absent	Null	0.0	Null	0.0	Null	0.0	Null	0.0
	Presence	39	100.0	39	100.0	39	100.0	39	100.0
k4	Absent	Null	0.0	Null	0.0	Null	0.0	Null	0.0
	Presence	39	100.0	39	100.0	39	100.0	39	100.0

Table III: Correlation of Mathlab Value with Variables (Pearson Correlation Test)

		Age	Height	Weight	BMI	Subcutaneous Adipose Tissue
MATLAB	r	0.032	-0.349	0.302	0.654	0.420
	p-value	0.846	**0.029**	0.062	**<0.001**	**0.008**

Table IV: Radiologist and Inter-Measurement Kappa Values

	Measurement R1-R2		Measurement R1-R2		Rad1 1-2		Rad 2 1-2	
	kappa	p-value	kappa	p-value	kappa	p-value	kappa	p-value
K1	*		*		*		*	
K2	0.712	**<0.001**	0.827	**<0.001**	0.712	**<0.001**	0.827	**<0.001**
K3	*		*		*		*	
K4	*		*		*		*	

**statistical full compatibility.*

Table V: MATLAB, Age, BMI Comparisons

	Gender	Mean	Std. Deviation	p-value
MATLAB measurements	M	49.8568	18.97786	0.161
	F	58.7486	17.92665	
Age	M	48.00	15.379	0.178
	F	54.79	13.656	
BMI	M	27.872	3.5570	0.803
	F	28.157	3.1082	

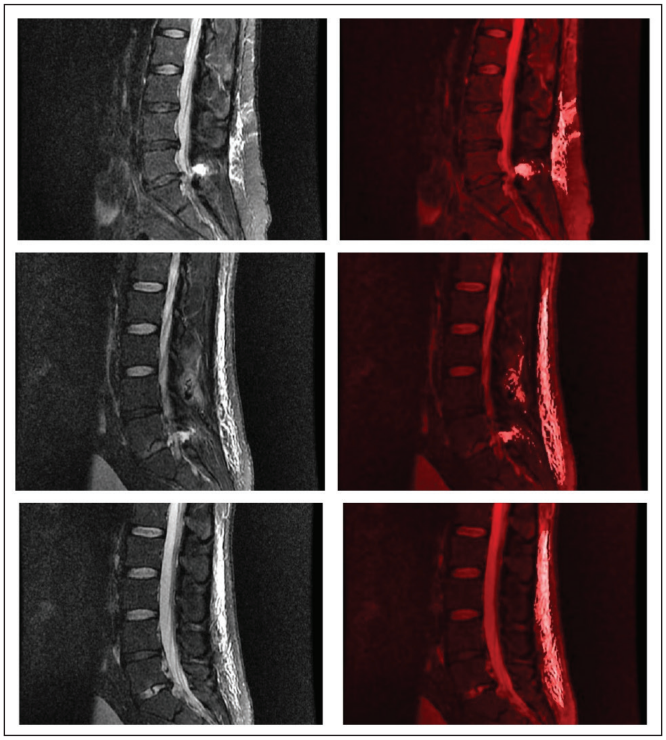

Figure 2: Matrix laboratory sample figures were shown.

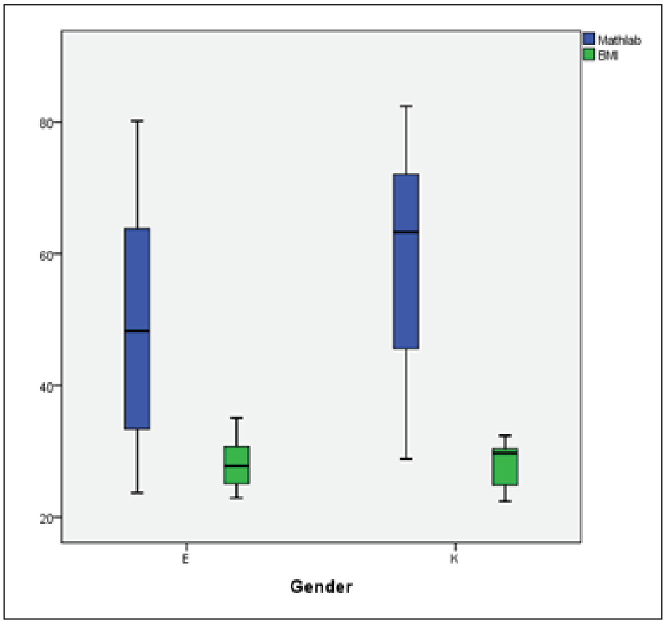

Figure 3: The comparison of BMI and MATLAB values.

MATLAB Studies

First, the MR image was read by matrix laboratory and shown to the user for the selection of the possible edema area so as to limit the region and eliminate miscalculations because of the higher water content of different tissues. In the selected region, the total number of pixels with a value higher than the threshold value (260 for this study) was calculated. Then, the value obtained was multiplied by the actual pixel size (0.55x0.55 mm) to determine the total edema area. This algorithm was applied to the three consecutive images where the edema existed for each patient. All the regional areas were summed; this sum was assumed to represent the total edema content for that patient in an objective manner.

DISCUSSION

The detected clinical complications were in the form of subcutaneous edema, ascites, or cellulitis. However, none of these symptoms were encountered in these patients. No fluid accumulation was observed around the dura mater, possibly due to the physiological movement with the pulsation of the dura

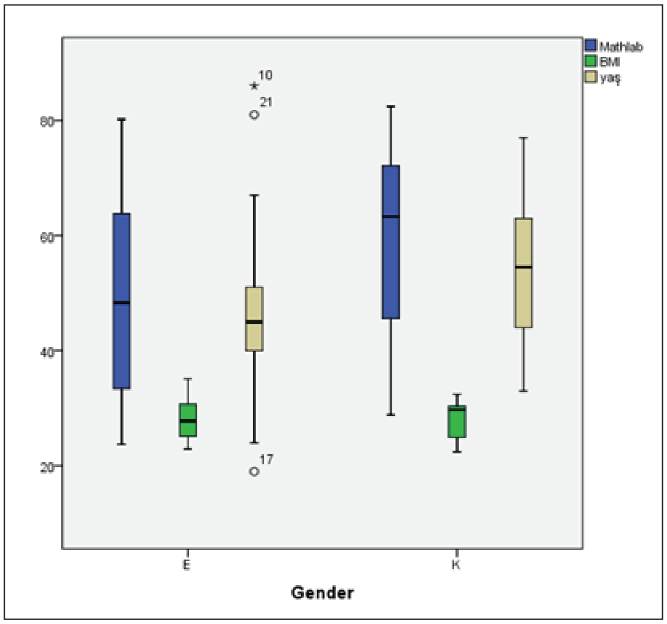

Figure 4: The comparison of BMI, age and MATLAB values by gender.

mater. The demographic characteristics were referred to as one of the variable factors of the study. In our study, the most striking findings was the correlation between BMI and matrix laboratory measurements. According to the results of this in vivo study, the relationship between BMI and accumulation into the surrounding anatomical tissues during UBE was found to be remarkable. However, this relationship was not related to gender. The basic physiological effects of BMI on the subcutaneous adipose tissues may lay the groundwork for these results. This correlation seems to continue in the inter-observer radiologist measurements, as per the reliability statistical measurements. The encountered results that were compatible with the paper of Hong et al. were found in this study (7). The use of two separate portals in the operations carried out with the unilateral biportal endoscopic (UBE) technique causes unavoidable fluid accumulation in the normal anatomical structures in the close environment of the operation area. In endoscopic interventions, one of the most important complications is accumulation of epidural fluid. But this fluid accumulation does not result in any complications.

Among the spine surgery techniques, UBE is a special endoscopic surgical technique that could be performed using two portals (11). UBE has a clear visualization with fluid in the spinal surgical area (4). The continuation of this visual comfort was directly related to water dynamics and tissue bleeding pressure. In addition, it was clear that fluid accumulation into the soft tissues employed these biophysics laws together with the findings obtained. With CUSUM analysis, Chen et al. found that the learning curve was completed with 24 cases. UBE has a long learning curve and it involves a serious course process (5). Semitubular retractor can help keep the working portal open during the surgery. If the working portal is kept open, fluid accumulation is extremely low when compared with the use of free-hand approach.

Akpolat et al. applied the matrix laboratory model to restore the global sagittal balance, especially the sagittal vertical axis, in ankylosing spondylitis. This model was reliable for spinal studies (2). In a cohort study conducted in China, matrix laboratory studies were found to be more successful with the biomechanical computed tomography (BCT) than DXA-measured areal bone mineral density (aBMD) for predicting the vertebral mechanical characteristics (18). In another matrix laboratory study, adolescent idiopathic scoliosis was characterized by spinal mobility differences. They found that the scoliotic spine was flexible and possibly compensated near the apex (8). Moreover, Khalsa et al. used matrix laboratory, a semiautomatic 3D volumetric analysis of pre/postoperative lumbar CT views, to determine the radiographic grade of lumbar central stenosis with minimal bone removal from the lamina and facet joints in minimally invasive surgeries (9). To facilitate rational decision-making between minimally invasive surgery and open spine surgery, the algorithm was prepared using matrix laboratory. This minimally invasive spinal deformity surgery (MISDEF) algorithm guides spine surgeons in terms of inter- and intra-observer agreement (15). According to this past study, some fluid accumulates in the perioperative field, especially in the subcutaneous and muscle tissues, with the UBE procedure. In our study, this accumulated fluid was determined in the subcutaneous area as K2 and the interfacial area. With the MATLAB measurements, about 50-mm fluid accumulation was observed in the patients. The mean fluid accumulation for women was 58.75±18.870 (cm^3) and that for men was 49.86±18.977 (cm^3). The pertinent factors in this compartment may explain as: i) the importance of a liquid milieu was quantity and quality of it, ii) the hydrodynamics concepts, iii) the metabolic response to trauma in any tissue, iv) to determine the mean amount, to measure of water dynamics, to detect the relationship of boundaries and the relationship to other variables. The amount of these factors to consider is probably out of scope in the paper.

This study had some limitations. For instance, i) this study was retrospective, ii) the sample size was not small, but could have been larger, iii) the difference in races and settings were not compared, iv) all patients were included in this study after the process of removing the bone and ligament flavum, v) MATLAB measurements might be done under different conditions in other settings of water dynamics with UBE, vi) a comparison of pre- and post MRI STIR images would have been more useful, vii) the pre-operative values would have been studied because of a significant association of matrix laboratory values with BMI which is specific to the patient, vii) matrix laboratory was selected to measure the 3 more important cuts to calculate the total fluid volume in 4 compartments. Describing MRI sections of 0.55 mm with interspace of 5 mm makes this calculation very primitive, viii) We have reported using semitubular retractor and have presented only the results obtained by this technique. It is not possible to claim the superiority of the semi tubular retractor to the free hand technique and the tubular retractor by this study.

CONCLUSION

UBE is becoming an increasingly popular technique in spine surgery. The use of fluid in UBE seems a safe technique. We believe that fluid accumulation in UBE is not a cause for any concern. We did not record any serious complications of fluid accumulation in the UBE study group. Also, matrix laboratory which was used to detect this fluid accumulation is a good measurement method in spine surgery. With matrix laboratory, we determined that the fluid accumulation in UBE was in the normal range of physiological limits. In addition, the following topics need to be explored in the future: i) comparison between experienced and beginner surgeons who are interested in the UBE surgery; ii) fluid accumulation in other UBE procedures (UBE with cage interbody fusion, percutaneous posterior instrumentation, etc.) can be investigated; iii) comparison between groups of patients with or without semitubular retractor, iv) the effect of the extent of the opening of working port on fluid accumulation needs further discussion and literature support, v) the relationship between UBE experience and fluid accumulation may be an objective of our future study.

Declarations

Funding: There is no funding for this study.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: OB, KY

Data collection: HA

Analysis and interpretation of results: BA

Draft manuscript preparation: HA

Critical revision of the article: OB, KY, HA

Other (study supervision, fundings, materials, etc...): OB, KY, BA, MO, EG

All authors (OB, KY, BA, HA, MO, EG) reviewed the results and approved the final version of the manuscript.

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