Original Article

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Evaluating Efficiency of Time Use and Operational Costs in a Breast Clinic Workflow: A Comparative Analysis Between Automated Breast Ultrasound and Handheld Ultrasound

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ABSTRACT

Objective: The aim of this study was to evaluate efficiency of time use for radiologists and operational costs of automated breast ultrasound (ABUS) versus handheld breast ultrasound (HHUS).

Materials and Methods: This study was approved by the Institutional Review Board, and informed consent was waived. One hundred and fifty-three patients, aged 21–81 years, underwent both ABUS and HHUS. The time required for the ABUS scanning and radiologist interpretation and the combined scanning and interpretation time for HHUS were recorded for screening and diagnostic exams. One-Way ANOVA test was used to compare the methods, and Cohen Kappa statistics were used to achieve the agreement levels. Finally, the cost of the methods and return of interest were compared by completing a cost analysis.

Results: The overall mean ± standard deviation examination time required for ABUS examination was 676.2±145.42 seconds while mean scan time performed by radiographers was 411.76±67.79 seconds, and the mean radiologist time was 234.01±81.88 seconds. The overall mean examination time required for HHUS was 452.52±171.26 seconds, and the mean scan time and radiologist time were 419.62±143.24 seconds. The reduced time translated into savings of 7.369 TL/month, and savings of 22% in operational costs was achieved with ABUS.

Conclusion: The radiologist's time was reduced with ABUS in both screening and diagnostic scenarios. Although a second-look HHUS is required for diagnostic cases, ABUS still saves radiologists time by enabling a focused approach instead of a complete evaluation of both breasts. Thus, ABUS appears to save both medical staff time and operational costs.

Keywords: Automated breast ultrasound; handheld ultrasound; radiologist; time savings; operational cost

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Key Points

- Total time needed for the ultrasound examination was greater with automated breast ultrasound (ABUS), yet it demands less time from radiologists compared to handheld breast ultrasound.
- Radiologist time is reduced across both screening and diagnostic scenarios with ABUS by allowing a targeted approach to certain breast areas rather than necessitating a thorough evaluation of the entire breast.
- ABUS has the potential to enhance the efficiency of human resource allocation and result in cost savings.

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Introduction

Screening mammography in women with large breasts may have a sensitivity as low as 30%–48% (1). Furthermore, studies show that women with extremely dense breast tissue have a lifetime risk of developing breast cancer up to six-fold higher than those with fatty breast tissue (2). Breast cancer screening with handheld breast ultrasonography (HHUS) in women with dense breast tissue has been shown to increase breast cancer detection rates by approximately three to four cancers per 1.000 women (3). Moreover, ultrasonography is the primary technique used in diagnostic settings to differentiate benign and malignant breast tumors.

There are several significant drawbacks to HHUS, including operator dependence, lack of standardization and repeatability, and long acquisition periods. Another restriction is the time required for the US screening exam, which was reported as a mean of 19 minutes in the ACRIN trial (4). Engaging in manual ultrasonography by a radiologist proves to be both time-intensive and costly. The cumulative time taken by a radiologist for conducting, interpreting, and dictating a report for ultrasonographic screening might extend up to 25 to 30 minutes. Additionally, a shortage of available radiologists presents another challenge.

Automatic breast ultrasound (ABUS) was designed to eliminate some of the drawbacks of HHUS. This novel ultrasonography technique makes reproducibility feasible by delegating data acquisition to the technician while reserving data interpretation for the radiologist. Moreover, standardizing breast ultrasound procedures and conserving valuable radiologist time offer additional advantages. ABUS was approved by the Food and Drug Administration in 2012 as a complementary screening tool for women with heterogeneous and extremely dense breasts. It has been shown that there is no statistically significant difference between ABUS and HHUS in terms of diagnostic performance (5). Although ABUS detects fewer lesions than HHUS, it is a reliable method for detecting malignancy in dense breasts (6-8).

Recent research has demonstrated that ABUS can also be used for diagnostic applications, including staging breast cancer, evaluating the tumor response to neoadjuvant chemotherapy, and a second look tool to complement magnetic resonance imaging (9-11). However, this approach lacks some advantages of HHUS, such as better axillary imaging and the ability to assess a lesion's elasticity and vascularization. Second-look HHUS may be needed to verify some lesions detected after ABUS and to evaluate further parameters, such as Doppler US imaging and US elastography.

Within the existing literature, the examination time of ABUS is reported to range between 10–30 minutes, although a consistent estimate is often reported at 15 minutes (12-14). This duration tends to decrease as technicians develop familiarity with breast sonographic anatomy and accumulate experience during the learning phase (14). In different studies, the interpretation time of ABUS varies between 2.9 and 9 minutes (12, 15, 16).

The aim of this study was to compare HHUS and ABUS examination times, observe the change in radiologists' time when ABUS is included in the workflow, and compare the operation costs of the two methods regarding time-saving.

Materials and Methods

Study Design

This prospective, single-center study was approved by the Institutional Review Board, and patient consent was obtained from each participant. Four breast radiologists with 5–25 years of experience in breast imaging and three well-trained radiology technicians/radiographers participated in this study. All patients were evaluated by one of four radiologists. One radiologist examined the patient with HHUS, and another radiologist evaluated the same patient with ABUS images blindly. The time required for the ABUS scanning and radiologist interpretation and the combined scanning and interpretation time for HHUS were recorded for screening and diagnostic exams.

A stopwatch was employed to determine the duration of examination and reading times for both ABUS and HHUS. In the case of ABUS, timing commenced once the probe was positioned on the patient and concluded upon the completion of all acquisitions. Secondly, timing started when the radiologist began the assessment of images on the workstation and ceased when all images were interpreted, and data was sent to the PACS. For HHUS, the timing commenced when the radiologist placed the probe on the breast and persisted until the image acquisition was finalized. To measure the reading time for each case using ABUS and HHUS, the radiologist's initiation of opening the patient file on the workstation marked the start, and the conclusion of report dictation marked the end. In summary, the acquisition, interpretation, and reading times were evaluated individually for ABUS. In contrast, for HHUS, only the examination and reading times were documented, with no measurement of interpretation time since the radiologist conducted interpretation simultaneously with the HHUS examination itself.

This study was approved by the Acıbadem Mehmet Ali Aydınlar University Medical Research Evaluation Board (date: 12.03.2020, no: 2020-04/17).

Study Population

The study included women who consecutively attended a single clinic for opportunistic screening or diagnostic workup between 1st July 2021 and 1st August 2021. One hundred and fifty-three patients, aged from 21 to 81 years, underwent both HHUS and ABUS examinations. Women who had a history of breast cancer, who had breast implants, who were lactating, or who had inflammatory skin conditions were excluded. Patients who refused to undergo both procedures were also excluded.

Ultrasound Imaging

HHUS examinations were performed with GE LOGIQ S8 and GE LOGIQ E10S plus (GE Healthcare, WI, USA) using a linear high-frequency probe (6–15MHz and 4–20 MHz, respectively). The subjects were examined in the supine position in at least two orthogonal views for each breast. All the lesions detected during the examination were recorded with at least two orthogonal views. Necessary additional examination methods, such as Doppler US, were used if needed.

The subjects underwent imaging of the breasts using ABUS (Invenia™ ABUS, GE Healthcare, WI, USA) scanner performed by radiographers. Standard images of both breasts (anteroposterior, lateral, and medial views) were acquired in the supine posture. Additional superior and inferior images are also obtained for large breasts. The ABUS Invenia system consists of a scan station with a linear transducer that automatically operates at a 6–14 MHz frequency and has a wide field of view (15.4 cm). The images have a 0.5 mm thickness. To accurately locate the nipple position in each position, a nipple marker was placed on the coronal view. These images are immediately routed to a dedicated workstation (sonoVIEWer Workstation) for post-processing. On the workstation's monitor, two dimensional (2D) pictures and three dimensional (3D), multiplanar reconstructions of three orthogonal planes were assessed.

Data Collection and Statistical Analysis

The examination time and the radiologist's interpretation times were recorded separately for ABUS. For HHUS, examination time, which is a combination of scanning and interpretation times, was recorded. The reporting time was recorded for each method separately.

The results were evaluated under four main headings: overall examination time, exam type (ABUS/HHUS), breast density (BI-RADS category A/B/C/D), and breast volume (cup size A/B/C/D). The radiologist's overall time for each patient according to exam type and breast density categories was cross-tabulated. During cross-tabulation, time (minutes) was classified into five groups: 0–3, 3–6, 6–9, 9–12, and 12–15 minutes. Cohen Kappa statistics were used to achieve the agreement levels. According to Cohen's approach, negative kappa ratios indicate no agreement or disagreement, 0–0.20 as slight agreement, 0.21–0.39 as minimal agreement, 0.40–0.59 as weak agreement, 0.60–0.79 as moderate agreement, 0.80–0.90 as strong agreement, and above 0.90 as almost perfect agreement.

The one-way ANOVA test was used to determine p values with a confidence interval of 95% and a $p<0.05$ considered statistically significant.

Cost Analysis

Radiologist costs per patient and fixed technician salaries were considered in the financial analysis. The cost of the methods was compared by completing a cost analysis, which focused on the calculation of return of investment (ROI) of both screening methods.

To compare the ROI of ABUS and HHUS, net profits and total investments of both methods were used. In detail, ROI is calculated as follows: *ROI = (Net Profit * 100) / Total Investment.* The depreciation expenses are calculated via a linear amortization method, assuming a useful life of 10 years and zero book value. In detail, the total investment was divided by the number of years, which leads to yearly depreciation expense.

HHUS revenue was determined by factoring in the absence of ABUS and incorporating additional HHUS examinations beyond ABUS, which was estimated as 62 more examinations per month.

For the respective salary expenses, the calculation was as follows:

For ABUS: Salary Expenses = patient number * median radiologist evaluation time = total radiologist spent time as hours * radiologist hourly fee and additionally technician salary was added.

For HHUS: HHUS revenue was determined by factoring in the absence of ABUS and incorporating additional HHUS examinations beyond ABUS, (62 extra per month). Salary Expenses = patient number * median radiologist examination time = total radiologist spent time as hours * radiologist hourly fee and additional HHUS examinations * median radiologist examination time and radiologist hourly fee was added.

For USD/TL currency, we used the end of January 2022 spot rate which was USD/TL = 13.567.

Results

Time Savings

The mean time required for ABUS examination (scanning, interpretation, and reporting time) and for HHUS examination (scanning and reporting time) are given in Table 1. The median reporting time is 13s (range 4–265s) for HHUS and 14s (range 6–212s) for ABUS. For screening group of patients, the median reporting time was 13s (4–118s) for HHUS and 16s (6–145s) for ABUS. For diagnostic group the median reporting time was 53s (6–265s) for HHUS and 44s (7–212s) for ABUS.

In terms of the radiologists' overall time for each patient, there was a significant difference between ABUS and HHUS (kappa= -0.07, $p<0.01$). ABUS requires a longer process for each patient while providing a significantly shorter involvement time for radiologists ($p<0.05$, see Figure 1). Radiologists saved a mean of 158.44 sec

Table 1. Comparison between the mean time for various elements of the ABUS versus HHUS examinations

	Mean (seconds)	Standard deviation	*p*
Reporting time			
HHUS	32.90	37.93	0.55
ABUS	30.42	34.59	
Radiologist's time			
HHUS	419.62	143.24	<0.05
ABUS	234.01	81.88	
Scan time			
HHUS	419.62	143.24	0.54
ABUS	411.76	67.79	

ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

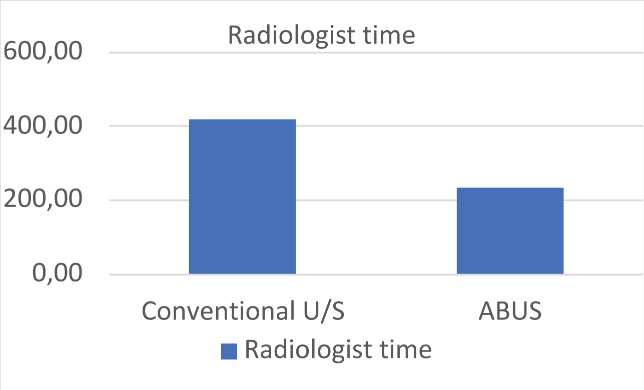

Figure 1. ABUS vs conventional US (HHUS) in regard of radiologist time

ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

Table 2. Statistical analysis of ABUS and HHUS times in minutes according to examination type

	Screening			Diagnostic		
	Mean	**Standard deviation**	***p*-value**	**Mean**	**Standard deviation**	***p*-value**
Report time						
HHUS	21.14	23.14	0.97	54.02	50.11	0.44
ABUS	21.26	19.64		44.38	43.82	
Radiologist time						
HHUS	375.38	110.03	<0.05	496.29	164.62	<0.05
ABUS	217.15	57.95		253.75	93.18	
Scan time						
HHUS	375.38	110.03	0.05	496.29	110.03	0.005
ABUS	401.51	70.72		430.88	70.72	
Overall examination time						
HHUS	396.53	125.05	<0.05	550.31	200.62	<0.05
ABUS	639.92	112.85		729.02	157.33	

ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

(approximately 3 minutes) for each case using ABUS; 2.6 minutes for screening exams and 4.04 minutes for diagnostic exams (Table 2, Figure 2). A summary of the findings for screening cases is given in Table 3.

Reporting time was similar for ABUS and HHUS (kappa=0.29, p=0.13).

As breast density increased, the scanning and interpretation times significantly increased using HHUS (Figure 3). Whereas when using ABUS, the radiologist interpretation time increased, but the scanning time remained similar.

The same pattern of findings was also observed for each breast volume. ABUS had a significantly shorter processing time for each size compared to HHUS (p<0.05).

Cost Savings

The reduced time translated into an annual savings of 7369 TL/month (based on 665 patients/month). That included the radiologist time cost and 5.500 TL for technician time cost. This would translate to a 22% savings in operational costs using ABUS. The details of net profit calculation for both methods is summarized in Table 4.

ABUS and HHUS costs were calculated as 256.614 TL and 282.514 TL, respectively.

For the respective salary expenses, the following details are given below:

For ABUS - Salary Expenses for 665 patients (each 3'45" radiologist time) = 149,625 seconds = 41.56 hours; thus, 350 x 41.56 = 14,546 TL; in total plus technician salary altogether 14,546 + 5,500 = 20,046 TL

For HHUS - Salary Expenses for 665 patients (each 16'37" radiologist time) = 663,005 seconds = 184.17 hours; thus, 350 x 184.17 = 64,460 TL and for 62 patients (each 17'10") = 63,860 seconds = 17.74 hours; therefore, 350*17.74 = 6,209 TL; in total 64,460 + 6,209 = 70,669 TL

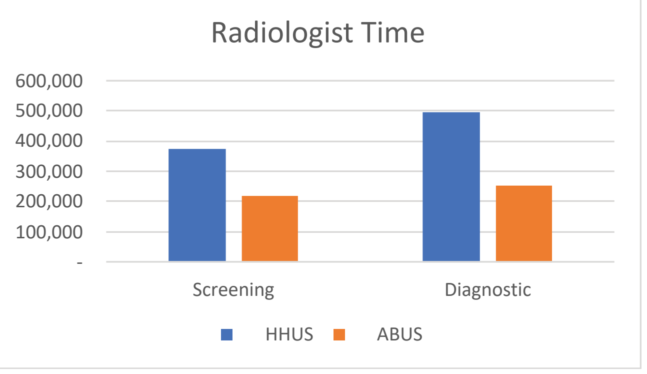

Figure 2. Radiologist time for screening and diagnostic cases compared for ABUS and HHUS

ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

Thus, the ROI for both methods can be calculated as follows;

ROI (ABUS) = (Net Profit (ABUS) * 100)/Total Investment (ABUS) =194,769.8*100/(200,000*13.567) = 7.18%

ROI (HHUS) = (Net Profit (HHUS) * 100)/Total Investment (HHUS) = 186,909.9*100/(65,000*13.567) = 21.2%

Discussion and Conclusion

ABUS has become used increasingly for the diagnosis of breast cancer in adjunct screening. As ABUS becomes more common, concerns have been raised about the time needed for radiologist interpretation of the test. Few studies have compared the examination times of HHUS and ABUS. However, comparison between the two techniques is essential, especially if time is a limiting issue. In this prospective study, comprehensive ABUS examination, encompassing both scanning and interpretation, required more time compared to HHUS, where radiologists conducted and interpreted the examination simultaneously due to the nature of HHUS interpretation occurring alongside the exam. The present study showed that adoption of ABUS, rather

Table 3. Summary table of screening cases

					HHUS		ABUS	
	Kappa	***p*-value**	**F**	**F crit**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Exam type								
Screening	-0.08	0.00	157.04	3.89	375.38	12106.07	217.15	3357.76
Diagnostic	0.07	0.00	10.54	4.23	431.43	13603.49	271.50	20359.65
Breast volume								
A	-0.08	0.00	11.16	4.60	406.25	24974.50	198.88	5864.41
B	-0.03	0.00	47.60	3.94	363.35	11755.23	224.61	8057.70
C	-0.04	0.00	124.06	3.99	384.59	4490.19	230.74	1996.81
D	-0.15	0.00	25.44	4.10	416.10	23420.83	221.15	6456.03
Breast density								
A	0.25	0.01	10.41	4.60	365.25	1763.64	266.38	5748.27
B	-0.10	0.00	20.31	4.04	371.24	17529.11	241.12	3313.94
C	-0.10	0.00	85.76	3.92	380.36	11990.37	216.57	7091.55
D	-0.12	0.00	47.73	4.15	414.53	12607.76	205.59	2941.76
Report time	0.29	0.72	0.13	3.88	23.05	553.01	24.24	697.97

ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

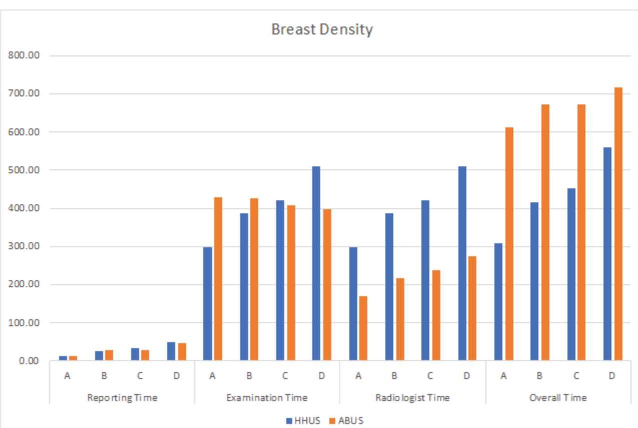

Figure 3. Time required for scanning and interpretation based on breast density

than HHUS, for breast ultrasound examinations, led to an average radiologist's time saving of 3.06 minutes per patient. Further detailed assessment of the data showed this was made up of 2.6 minutes for screening exams and 4.04 minutes for diagnostic exams. Both screening and diagnostic cases benefited from this reduction in waiting time. ABUS nevertheless showed time-saving benefits for radiologists by allowing a targeted approach to certain breast areas rather than necessitating a thorough evaluation of the entire breast, even though there may be a need for a secondary conventional ultrasound in some diagnostic cases.

Brunetti et al. (17) observed that ABUS examination and combined examination and interpretation times were longer than HHUS and that the time required by radiologists was longer for ABUS. They reported that even the interpretation time of ABUS alone took longer than the execution time for HHUS, varying between 4.5 and 11

Table 4. Profit calculations of ABUS and HHUS (in Turkish Lira)

	HHUS	**ABUS**
Revenue	282.514	256.614
Salary expenses	70.669	20.046
Maintenance expenses	1.333,3	2.250
EBITDA	210.511,7	234.318
Depreciation expenses	7.348,8	22.611,7
EBIT	203.162,9	211.706,3
Interest expenses	0	0
EBT	203.162,9	211.706,3
Tax	16.253	16.936,5
Net profit	186.909,9	194.769,8

EBITDA: Earnings Before Interest, Tax, Depreciation, Amortization; EBIT: Earnings Before Interest, Tax; EBT: Earnings Before Tax; ABUS: automated breast ultrasound; HHUS: handheld breast ultrasound

minutes for ABUS and 5.2±1.5 minutes for HHUS. Nonetheless, the research involved performing HHUS by radiologists of moderate experience, whereas ABUS assessments were conducted by radiologists who lacked familiarity with ABUS. In contrast, in the present study, all the ABUS readers had more than three years of experience with ABUS evaluation. A recent study of ABUS found a reduction in evaluation time as experience accumulated (18). We believe that the difference in ABUS evaluation time between the present study and that of Brunetti et al. (17) arises from disparities in radiologist experience with the system. Furthermore, in the Brunetti et al. (17) protocol, HHUS interpretation was carried out with the benefit of mammography findings differently from ABUS interpretation, which may have decreased HHUS time. However, in other studies (6, 13, 16, 19), the interpretation time of ABUS (around 3 minutes) was much less than the time needed for HHUS. Some other studies reported ABUS reading time of 2.9 and 9 min (15, 20). To summarize, the presence of various lesions, varying levels of experience of the observer, different devices and hardware, and different workflows could all contribute to this diversity.

In a daily workflow, ABUS saves the radiologist time when dealing with screening cases (6). These cases can be examined, and the images can be evaluated after the patient leaves the clinic, allowing an evaluation during less busy hours of the day. Radiologists use HHUS to confirm suspicious results. The initial ABUS screening reduces the workload enabling the radiologist to focus on the problem rather than performing a whole breast scanning. In diagnostic cases, an online evaluation was necessary, and a second look HHUS may be needed in some cases for assessment of the requirement for further workup, such as Doppler US, elastography, or biopsy. ABUS aids in saving radiologists' time by enabling a focused approach instead of a thorough evaluation of both breasts.

In the present study, when using HHUS scanning time and radiologist interpretation time both increased considerably when breast density increased. However, using ABUS, the radiologist interpretation time increased while the technician's scanning time remains relatively constant. In contrast, cup size had an effect on radiologists' times using both HHUS and ABUS. HHUS execution and ABUS interpretation times increased in parallel with the breast volume.

The reduced time spent by radiologists in performing scans translated into an annual saving of 22% in operational costs with ABUS. Based on the data, a ROI calculation for January 2022 indicated that the investment in HHUS, five years previously, had a return almost three-fold higher than that of ABUS. We expect this gap between the returns to decrease in the medium and long run due to the recovery of the investment over its lifetime. Additionally, it would be more accurate to calculate the ROI over the years for this type of investment. However, financial expenses (interest, etc.) of the relevant company were not included in the analysis. If there are such expenses, adding them may enable us to highlight the "positive" effect of ROI on ABUS. While the initial ROI assessment of ABUS stands at one-third of HHUS, this evaluation was preliminary, without factoring in the influence of ABUS on patient experience, workflow optimization, and reduced radiologist workload. Taking into consideration improved work conditions and the potential for better ROI over time in the long run, ABUS could be deemed a substantial investment. However, examination fees were standardized for both ABUS and HHUS. It might be necessary to consider a downward adjustment for ABUS examination fees.

Our study has some limitations. Firstly, it is a single-center experience and a multicenter approach would provide a more comprehensive depiction of study timelines. Second, the number of patients included in the study was limited. A study involving a larger volume of subjects would offer a more accurate representation of real-life scenarios. Third, the awareness among staff carrying out clinical interpretation that time was being monitored might have introduced a bias towards either method. Fourth, the revenue calculations were conducted generally, potentially resulting in a significant disparity in ROI between the methods. Lastly, this study was designed in a setting where HHUS is performed by radiologists only. This circumstance emphasizes the need for an automated system to relieve radiologists from performing numerous screening US that are likely to show normal or benign results in the majority of cases. In a setting where ultrasonographers perform HHUS, the savings found in this study may not apply.

In conclusion, the present study demonstrated that the total time needed for the procedure was longer with ABUS, yet it demands less radiologist's time compared to HHUS. Radiologist time is reduced across both screening and diagnostic scenarios with ABUS. Therefore, we suggest that ABUS has the potential to improve expert human resource allocation and result in overall cost savings.

Ethics Committee Approval: This study was approved by the Acıbadem Mehmet Ali Aydınlar University Medical Research Evaluation Board (date: 12.03.2020, no: 2020-04/17).

Informed Consent: Informed consent was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: N.G., E.Y., E.B.T., E.A.; Concept: N.G., Ö.K., E.Y., E.B.T., E.A.; Design: A.A., K.T., H.C.A., E.A.; Data Collection or Processing: S.U., Ö.K., A.A., K.T., H.C.A.; Analysis or Interpretation: N.G., S.U., Ö.K., E.Y., E.B.T., E.A.; Literature Search: A.A., K.T., H.C.A., E.Y.; Writing: N.G., S.U., Ö.K., E.B.T., E.A.

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