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Quantifying the effect of shoulder size on operation duration: an analysis of stapes surgery outcomes

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Main Article

Christian G Fritz takes responsibility for the integrity of the content of the paper

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Abstract

Objective. To investigate the effect of body mass index on hearing outcomes, operative time and complication rates following stapes surgery.
Method. This is a five-year retrospective review of 402 charts from a single tertiary otology referral centre from 2015 to 2020.
Results. When the patient's shoulder was adjacent to the surgeon's dominant hand, the average operative time of 40 minutes increased to 70 minutes because of a significant positive association between higher body mass index and longer operative times (normal body mass index group (<25 kg/m^2) r = 0.273, $p = 0.032$; overweight body mass index group (25–30 kg/m^2) r = 0.265, $p = 0.019$). Operative times were not significantly longer upon comparison of low and high body mass index groups without stratification by laterality (54.9 ± 19.6 minutes *vs* 57.8 ± 19.2 minutes, $p = 0.127$).
Conclusion. There is a clinically significant relationship between body mass index and operating times. This may be due to access limitations imposed by shoulder size.

Introduction

Obesity is on the rise in the USA. According to the Centers for Disease Control and Prevention criteria, 42.4 per cent of adults in the USA are obese.[1] Numerous studies suggest that obesity leads to longer operative times and increased complication rates.[2–4] Although prior reports demonstrate that obesity can affect several otolaryngological diseases, the effect of patient weight on otological surgery remains less clear.[5–7] Body mass index (BMI) and body habitus may present unique challenges for ear surgery because the patient's shoulder can interfere with surgical access. In particular, when operating on the ipsilateral side to the surgeon's dominant hand (i.e. a right-handed surgeon operating on a right ear), a large shoulder may force the surgeon to alter their hand position, instrument grip and technical approach. Within the field of otolaryngology, otological surgery is known for requiring the utmost level of manual dexterity and precision. For this reason, outcomes may be especially susceptible to ergonomic aberrations imposed by body habitus variability.

In order to isolate the effect of shoulder interference on surgical procedures requiring access to the ear, the authors sought to study a common otological procedure with highly preserved anatomical relationships and relatively consistent surgical complexity. Stapes surgery addresses otosclerosis, a disease of the otic capsule that causes a conductive or mixed hearing loss.[8] There is an estimated histological prevalence of approximately 2.5 per cent; however, only 0.3–0.4 per cent of patients show clinical findings of the disease.[8] Patients tend to be Caucasian adults presenting in the third decade of life, of whom 70–80 per cent have bilateral disease.[9] Although conservative treatments such as fluoride supplementation and hearing aids are therapeutic options, stapes surgery is an effective surgical intervention for patients with otosclerosis. Surgery is reserved for patients with an air–bone gap (ABG) of greater than 35 dB without evidence of ossicular disruption.[6]

This report investigated the association between BMI and operative times, complication rates and hearing outcomes following stapes surgery. We hypothesised that surgical access limitations in patients with higher BMIs would result in prolonged operative times.

Materials and methods

After Institutional Review Board approval (study number: 1868685-1), a retrospective review of patients undergoing stapes surgery between January 2015 and December 2020 was performed. Exclusion criteria were: age of less than 18 years and missing post-operative follow-up notes. Among the 487 cases identified, 10 patients did not meet the age requirement and 15 patients did not have clinical follow-up documentation in their electronic medical records. Of the 462 patients included, 402 had complete pre- and post-operative audiometric results available. These cases represent the combined efforts of 10 surgeons at a single tertiary care institution, each of whom were fellowship-trained in otology, neurotology and skull base surgery.

Patients were stratified into weight groups based on Centers for Disease Control and Prevention definitions,[1] to yield underweight/normal weight (BMI < 25 kg/m^2) (n = 145) and overweight/obese (BMI ≥ 25 kg/m^2) (n = 317) cohorts for two-group analysis, with the latter cohort being further subdivided into overweight (BMI of 25 to <30 kg/m^2) (n = 173) and obese (BMI ≥ 30 kg/m^2) (n = 144) groups for a more comprehensive three-group analysis.

Primary outcome measures included operative time, hearing function and complications. Operative time was measured using surgery start and stop times recorded by the surgical circulating nurse. Hearing function was assessed by the change in ABG based on pure tone averages of four frequencies (0.5, 1, 2 and 4 kHz). Operative notes and post-surgical follow-up notes were reviewed to calculate complication frequency. Baseline characteristics including BMI and history of prior ipsilateral otological surgery were extracted from the pre-operative notes.

Results and analysis

A total of 462 patients met the inclusion criteria. Patients' baseline characteristics are shown in Table 1. There were no significant differences in mean (± standard deviation) operating time based on BMI according to the two-group analysis (low BMI (< 25 kg/m^2) = 54.9 ± 19.6 minutes *vs* high BMI (≥ 25 kg/m^2) = 57.8 ± 19.2 minutes; p = 0.127, t-test) and the three-group analysis (low BMI (< 25 kg/m^2) = 54.9 ± 19.6 minutes, overweight BMI (25 to < 30 kg/m^2) = 58.4 ± 19.5 minutes, and obese BMI (≥ 25 kg/m^2) = 57.2 ± 18.9 minutes; p = 0.269, analysis of variance).

A correlational analysis was employed to further analyse the effect of BMI on operative times. Among underweight/normal weight (BMI < 25 kg/m^2) patients, there was a statistically significant positive association between higher BMI and longer operative times (r = 0.170, p = 0.041) (Fig. 1a). There was no significant association between BMI and operative time when considering all patients as a single cohort (r = 0.070, p = 0.131) (Fig. 1d). A further sub-analysis excluding revision cases revealed a weak association between higher BMI and longer operative times, which approached the threshold for statistical significance (r = 0.098, p = 0.052) (Fig. 1h). Revision cases were defined as those in which ipsilateral stapes surgery was performed previously.

In order to specifically investigate the effect of shoulder hinderance on operative times, we analysed the relationships among operated ear laterality, surgeon's dominant hand and BMI. For surgical procedures where the patient's shoulder was contralateral to the surgeon's dominant hand (i.e. a right-handed surgeon operating on a left ear), there were no significant associations between BMI and operation duration (Fig. 2a–d). In contrast, when the patient's shoulder was adjacent to surgeon's dominant hand (i.e. a right-handed surgeon operating on a right ear), there was a significant positive association of higher BMI with longer operative times for normal weight (BMI < 25 kg/m^2) patients (r = 0.273, p = 0.032) and overweight (BMI 25 to < 30 kg/m^2) patients (r = 0.265, p = 0.019) (Fig. 2e–h).

Table 1. Summary of patients' baseline characteristics

Parameter	All patients	Patients with complete audiometry data	Revision cases	All patients *vs* complete audiometry *p*-value	All patients *vs* revision cases *p*-value
Number of patients	462	402	70		
Age (median (IQR); years)	50 (41.0–59.0)	50 (42.0–59.0)	53.5 (42.0–63.0)	0.901	0.063
Sex (*n* (%))					
– Female	296 (64.1)	258 (64.2)	46 (65.7)	0.973	0.789
– Male	166 (35.9)	144 (35.8)	24 (34.3)		
Laterality (*n* (%))					
– Left	241 (52.2)	210 (52.2)	33 (47.1)	0.983	0.433
– Right	221 (47.8)	192 (47.8)	37 (52.9)		
Prior ipsilateral surgery (*n* (%))	82 (17.7)	72 (17.9)	70 (100)	0.951	<0.0001*
Ipsilateral acoustic reflex (*n* (%))					
– Absent	363 (78.6)	315 (78.4)	36 (51.4)	0.932	<0.0001
– Present	7 (1.5)	5 (1.2)	1 (1.4)		
– Not tested	92 (19.9)	82 (20.4)	33 (47.1)		
Pre-operative audiometry (*n*)	402		62		
ABG (median (IQR); dB)	26.3 (20.0–32.5)	N/A	25.0 (16.3–36.3)	N/A	0.592
WRS (median (IQR); %)	100 (96–100)	N/A	96 (90–100)	N/A	0.055
SRT (median (IQR); dB)	50 (40–60)	N/A	50 (35–60)	N/A	0.724

*By definition, all revision cases had prior ipsilateral ear surgery. 'N/A' placeholder because of audiometric data being presented in 'All patients' column. IQR = interquartile range; ABG = air–bone gap; WRS = word recognition score; SRT = speech recognition threshold

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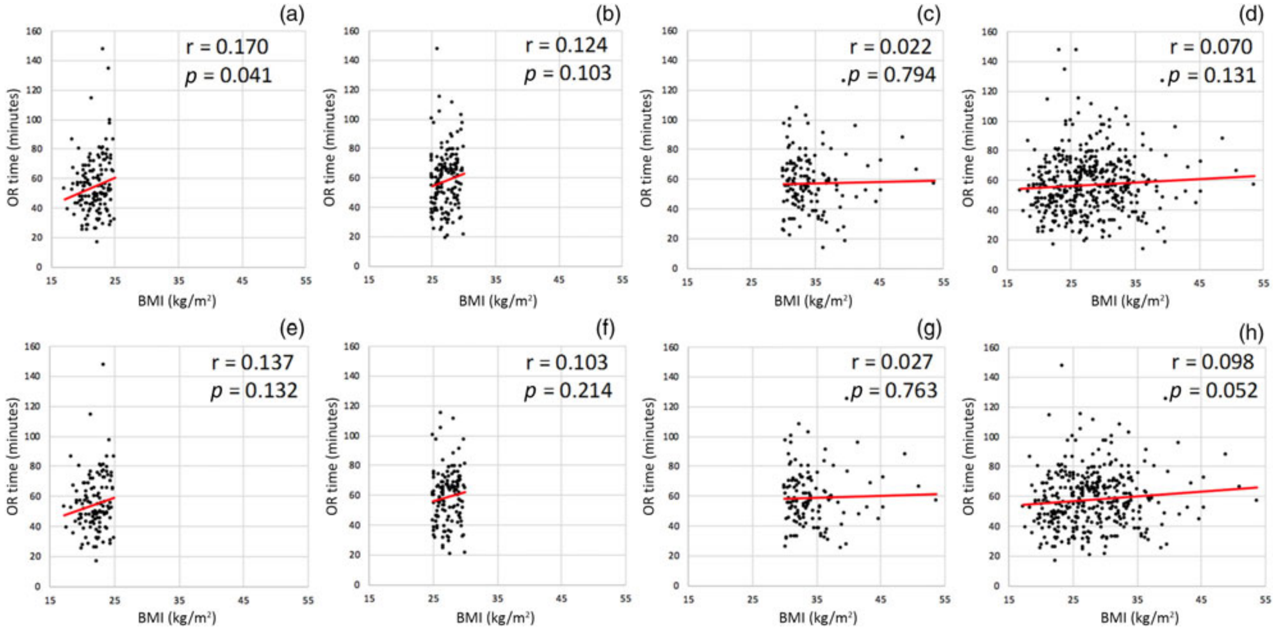

Figure 1. Association between body mass index (BMI) and operation duration (OR time) stratified by BMI cohorts: (a) BMI less than 25 kg/m^2, (b) overweight, (c) obese, (d) combined, (e) primary surgery for BMI less than 25 kg/m^2, (f) primary surgery for overweight, (g) primary surgery for obese, and (h) primary surgery (combined). Plots are shown for all patients, including revision cases (a–d) and primary stapes surgery only cases (e–h). Red lines represent linear trendlines, with corresponding Pearson correlation coefficient (r) and significance level (*p*) in the upper right of each plot.

For all patients, the average improvement in ABG was 17.0 dB, with a mean post-operative ABG of 10.6 dB. Among those with a higher BMI (≥ 25 kg/m^2), primary stapes procedures in which the patient's shoulder was adjacent to the surgeon's dominant hand had a greater improvement in ABG post-operatively as compared to patients in the lower BMI (< 25 kg/m^2) group (19.1 ± 9.9 dB *vs* 16.4 ± 10.2 dB) (p = 0.038). For the remaining groups, however, regardless of the patient's shoulder position relative to the surgeon's dominant hand, there was no significant difference in hearing outcomes (ABG improvement) or operative time (Table 2).

Overall complication rates were similar among low and high BMI groups (low BMI (60 of 145) = 41.3 per cent, *vs* high BMI (126 of 317) = 39.7 per cent; p = 0.740, chi-square test). Likewise, post-operative complaints were similar in frequency among the various BMI groups (Tables 3 and 4).

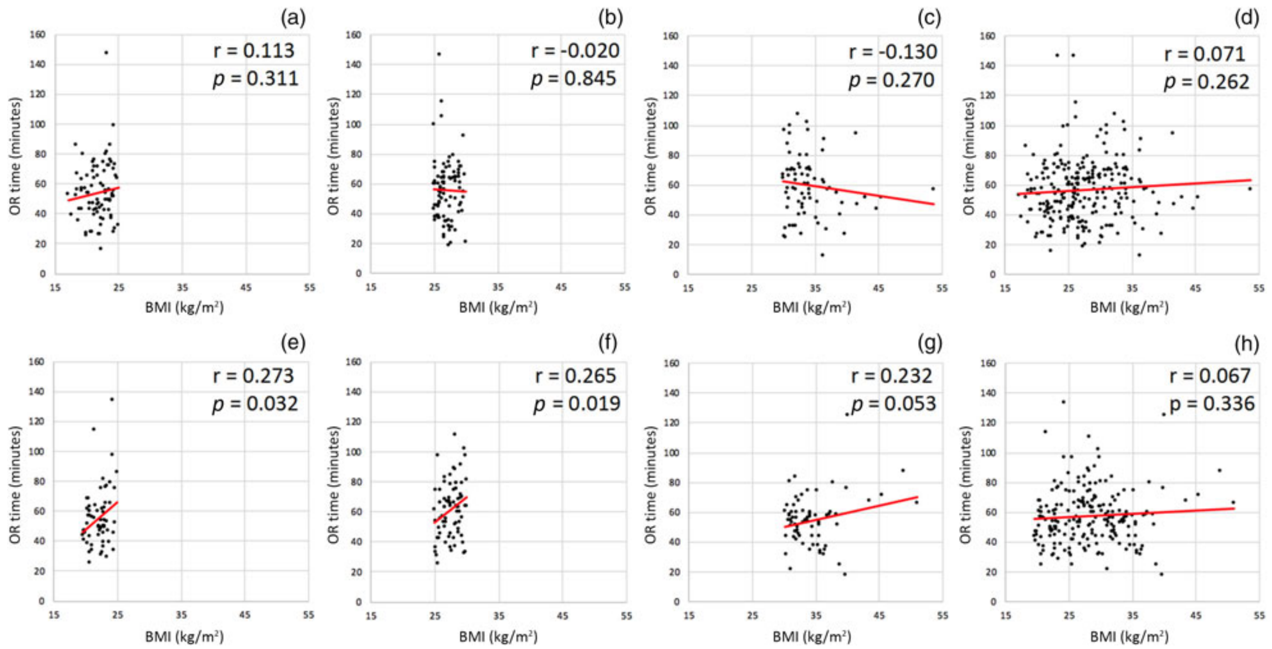

Figure 2. Association between body mass index (BMI) and operation duration (OR time) stratified by BMI cohorts: (a) surgeon's dominant hand opposite operative side for BMI less than 25 kg/m^2, (b) dominant hand opposite for overweight, (c) dominant hand opposite for obese, (d) dominant hand opposite (combined), (e) dominant hand adjacent to operative side for BMI less than 25 kg/m^2, (f) dominant hand adjacent for overweight, (g) dominant hand adjacent for obese, and (h) dominant hand adjacent (combined). Red lines represent linear trendlines, with corresponding Pearson correlation coefficient (r) and significance level (*p*) in the upper right of each plot.

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Table 2. Assessment of hearing outcomes and operative duration stratified by BMI cohort

Analysis	Surgery type	Laterality classification by BMI	Cases (*n*)	ABG improvement (dB)			Operative time (minutes)		
				Mean	SD	*p*-value	Mean	SD	*p*-value
2-group analysis	All patients (including revisions)	Low BMI (<25 kg/m^2)							
		– Opposite laterality	73	17.3	11.3	0.761	52.9	19.9	0.356
		– Adjacent laterality	50	16.7	12.2		56.4	21.3	
		High BMI (≥25 kg/m^2)							
		– Opposite laterality	148	16.4	11.1	0.191	57.3	20.4	0.471
		– Adjacent laterality	131	58.9	17.5		58.9	17.5	
	Primary stapes surgery (excluding revisions)	Low BMI (<25 kg/m^2)							
		– Opposite laterality	62	16.7	11.2	0.582	52.3	11.2	0.226
		– Adjacent laterality	40	18.0	10.5		57.2	18.6	
		High BMI (≥25 kg/m^2)							
		– Opposite laterality	128	16.4	10.2	0.038	58.7	18.4	0.824
		– Adjacent laterality	111	19.1	9.9		59.2	17.0	
3-group analysis	All patients (including revisions)	Low BMI (<25 kg/m^2)							
		– Opposite laterality	73	17.3	11.3	0.761	52.9	19.9	0.356
		– Adjacent laterality	50	16.7	12.2		56.4	21.3	
		Overweight BMI (25 to <30 kg/m^2)							
		– Opposite laterality	80	15.6	10.8	0.284	56.8	20.9	0.159
		– Adjacent laterality	66	17.7	12.1		61.5	18.4	
		Obese BMI (≥30 kg/m^2)							
		– Opposite laterality	68	17.4	11.5	0.479	57.8	19.9	0.642
		– Adjacent laterality	65	18.7	10.5		56.3	16.4	
	Primary stapes surgery (excluding revisions)	Low BMI (<25 kg/m^2)							
		– Opposite laterality	62	16.7	11.2	0.582	52.3	11.2	0.226
		– Adjacent laterality	40	18.0	10.5		57.2	18.6	
		Overweight BMI (25 to <30 kg/m^2)							
		– Opposite laterality	67	15.9	10.3	0.075	57.7	17.7	0.255
		– Adjacent laterality	55	19.2	9.6		61.3	17.2	
		Obese BMI (≥30 kg/m^2)							
		– Opposite laterality	61	16.9	10.2	0.259	59.8	19.3	0.425
		– Adjacent laterality	56	19.1	10.2		57.2	16.7	

'Opposite laterality' indicates that the surgeon's dominant hand was on the side contralateral to the patient's operative ear; 'adjacent laterality' indicates that the surgeon's dominant hand was on the same side as patient's operative ear. BMI = body mass index; ABG = air–bone gap; SD = standard deviation

Discussion

To the best of the authors' knowledge, this is the first study in the literature to comprehensively investigate the effect of BMI on operative time and surgical outcomes in otological surgery. Overall, we found that stapes surgery duration was influenced by patient BMI. Nevertheless, these procedures were performed successfully in patients regardless of BMI. The average improvement in ABG was 17.0 dB, with a mean post-operative ABG of 10.6 dB. Approximately 60 per cent of all patients achieved an ABG of less than 10 dB, which is consistent with previous reports.[10,11]

Without taking operated ear laterality into consideration, there was minimal association between BMI and operative times for all patients, when assessed either as a single cohort or in low/high BMI groupings. However, an in-depth correlational analysis revealed a significant positive association between higher BMI and longer operative times in several scenarios. When the effect of shoulder hinderance was amplified, such as when a right-handed surgeon was operating on a right ear in the setting of a BMI of more than 25 kg/m^2, the operative time was significantly longer in duration. While the surgery took longer in these cases, the hearing improvement outcomes remained similar to those of other BMI cohorts. This indicates that although the surgery can be more time-consuming, and may challenge the surgeon to alter their hand position to accommodate the patient's body habitus, the procedure ultimately can be performed safely and successfully.

Longer operative duration is not without its risks. Prolonged surgery increases the likelihood of complications and is a potentially modifiable risk factor for surgical site infections.[12–14] Emerging evidence also suggests that exposure to anaesthetics may be associated with a subtle decline in

Table 3. Frequency of post-operative complications and symptoms

Complication or symptom	Cases (*n* (%))
Any complaint	195 (42.2)
Transient vestibular compliant (dizziness, imbalance, vertigo)	97 (21.0)
Two or more complaints	36 (7.8)
Transient dysgeusia	35 (7.6)
Transient ear fullness or plugged sensation	30 (6.5)
No improvement in hearing (change in ABG of ≤0 dB)	23 (5.0)
Hyperacusis	9 (1.9)
Numbness of face or tongue	9 (1.9)
Post-auricular incision related infection, irritation or dehiscence	4 (0.9)
Otitis media with effusion	3 (0.6)
Otitis externa	3 (0.6)
Haemotympanum or bleeding from ear	3 (0.6)
Stapes 'gusher' syndrome	2 (0.4)
Stapes bone exposed in ear canal at incision line	2 (0.4)
Tympanic membrane perforation	1 (0.2)
Transient facial nerve weakness	1 (0.2)
Transient slurring of speech	1 (0.2)
Loose-wire syndrome (causing distortion of hearing)	1 (0.2)

ABG = air–bone gap

cognitive functioning in older adults.[15–18] Although less important than the aforementioned patient outcomes, healthcare economics are also intrinsically linked to operation duration. Some estimates suggest that the cost of operating theatre time can exceed $100 per minute.[19,20] Moreover, there is an opportunity cost for the otological surgeon to undertake, such as two procedures on patients with higher BMIs rather than three procedures on normal BMI patients during the same period of time. Taken together, body weight is a variable that may be worth taking into consideration for surgical scheduling purposes. Whether the trends delineated in this report extend to ear surgery as a whole remains to be determined. Future research pursuits should focus on independently analysing outcomes for cases in which there is concordance between operated ear laterality and the surgeon's dominant hand.

Interestingly, post-hoc statistical analyses revealed a thresholding effect with regard to the effect of BMI on operation duration. The association between higher BMI and an incremental prolongation of operation time was most pronounced in non-obese patients when the surgeon's hand was adjacent to the patient's shoulder. Among these patients, the average operation duration increased from approximately 40 minutes to 70 minutes as BMI rose from 15 to 30 kg/m^2 (shown by the red trend line in Fig. 2d, e). In contrast, within the obese patient cohort (BMI ≥ 30 kg/m^2), there was minimal increase in operation duration for those patients with the highest BMIs (Fig. 2e). The authors hypothesised that this was due to a thresholding effect that attenuates the effect of shoulder

Table 4. Assessment of complication frequency stratified by BMI cohort

Groups	Complication	*n* (%)	χ^2 value	*p*-value
2-group analysis	Any complication			
	– Normal/underweight (*n* = 145)	60 (41.3)	0.110	0.740
	– Overweight/obese (*n* = 317)	126 (39.7)		
	Transient vestibular complaint			
	– Normal/underweight (*n* = 145)	32 (22.1)	0.147	0.702
	– Overweight/obese (*n* = 317)	65 (20.5)		
	Transient dysgeusia			
	– Normal/underweight (*n* = 145)	11 (7.6)	< 0.001	0.995
	– Overweight/obese (*n* = 317)	24 (7.6)		
	Two or more transient post-operative symptoms			
	– Normal/underweight (*n* = 145)	11 (7.6)	0.012	0.911
	– Overweight/obese (*n* = 317)	25 (7.9)		
3-group analysis	Any complication			
	– Normal/underweight (*n* = 145)	60 (41.3)	2.881	0.237
	– Overweight (*n* = 173)	76 (43.9)		
	– Obese (*n* = 144)	50 (34.7)		
	Transient vestibular complaint			
	– Normal/underweight (*n* = 145)	32 (22.1)	0.164	0.921
	– Overweight (*n* = 173)	35 (20.2)		
	– Obese (*n* = 144)	30 (20.8)		
	Transient dysgeusia			
	– Normal/underweight (*n* = 145)	11 (7.6)	2.767	0.251
	– Overweight (*n* = 173)	17 (9.8)		
	– Obese (*n* = 144)	7 (4.9)		

(*Continued*)

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Table 4. (*Continued.*)

Groups	Complication	*n* (%)	χ^2 value	*p*-value
	Two or more transient post-operative symptoms			
	– Normal/underweight (*n* = 145)	11 (7.6)	1.250	0.535
	– Overweight (*n* = 173)	11(6.4)		
	– Obese (*n* = 144)	14 (9.7)		

BMI = body mass index

hinderance. It is likely that, beyond a certain weight, a case does not become proportionately more challenging or time-consuming. This may be due to the additional weight being distributed to areas of the body other than the supraclavicular fat pads, which does not necessarily impede surgical access for otological procedures.

A strength of this report is that all procedures were performed by fellowship-trained otologists at various stages of their careers. This enables variability in experience level to be normalised to some extent. Confounding variables such as those involving equipment, personnel and facilities were minimised given that all surgeons were in the same group, and operated at the same hospitals and surgery centres. The authors further confirmed that all cases utilised bilateral shoulder straps to help displace shoulders out of the surgical field. Moreover, all procedures utilised traditional binocular surgical microscopy, with no cases performed with endoscopic or exoscopic systems.

- Although otologists understand that it takes longer to operate when a large shoulder impedes surgical access, this phenomenon has never been rigorously quantified
- Higher body mass index (BMI) is associated with longer operating times for stapes surgery
- Average operation times increased from 40 minutes to more than 70 minutes with increasing BMI
- Shoulder interference depends on surgeon hand dominance and ear laterality
- There were no associations between BMI and hearing outcomes or complications

This study has several limitations. The potentially confounding factor of unique body habitus defined by waist-to-hip ratio within each BMI category was not accounted for because of the retrospective nature of this investigation. This is a potentially important variable given that each patient's body habitus and adipose tissue distribution may have a larger effect on surgical outcomes and operative times than BMI alone. Indeed, it is likely that an 'apple-shaped' body habitus with larger shoulder size would be disadvantageous in comparison to 'pear-shaped' bodies, as defined by canonical waist-to-hip ratio-based metrics. Despite this limitation, the senior authors assert that most patients with a higher BMI have a body habitus that causes shoulder encroachment into the surgical field and affects instrument manoeuvrability. Additionally, data on baseline patient characteristics often were collected from self-reported past medical history notes, which may be less reliable than objective measurements.

Conclusion

Stapes surgery was safely and effectively performed on patients regardless of BMI; however, a statistically significant association between higher BMI and longer operative times did exist when operating on ears ipsilateral to the surgeon's dominant hand. This association was not evident upon comparison of low and high BMI groups without stratification by laterality or when the operative ear was opposite to the surgeon's dominant hand. Spatiotemporal variables related to BMI should be considered, to optimise operative scheduling and pre-operative consultations. It is important for patients with a higher BMI to understand obesity-related surgical access hindrances that may necessitate a longer operation duration.

Competing interest. None declared

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