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Impact of body mass index on utilization of selected hospital resources for four common surgical procedures

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Background: Evidence about the impact of obesity on surgical resource consumption in the Australian setting is equivocal. Our objectives were to quantify the prevalence of obesity in four frequently performed surgical procedures and explore the association between body mass index (BMI) and hospital resource utilization including procedural duration, length of stay (LOS) and costs.

Methods: A retrospective cohort study of patients undergoing four surgical procedures at a tertiary referral centre in New South Wales, between 1 January 2016 and 31 December 2016, was conducted. The four surgical procedures were total hip replacement, laparoscopic appendectomy, laparoscopic cholecystectomy and hysteroscopy with dilatation and curettage. Surgical groups were stratified according to BMI category.

Results: A total of 699 patients were included in the study. The prevalence of obesity was significantly higher than local and national population estimates for all procedures except appendectomy. BMI was not associated with increased hospital resource utilization (procedural, anaesthetic or intensive care stay duration) in any of the four surgical procedures examined after controlling for age, gender and complexity. For other outcomes of hospital resource utilization (LOS and cost), the relationship was inconsistent across the four procedures examined. A high BMI was positively associated with higher LOS, medical costs and allied health costs in those who underwent an appendectomy, and critical care costs in those who underwent laparoscopic cholecystectomy.

Conclusion: Obesity was common in patients undergoing four frequently performed surgical procedures. The relationship between BMI and hospital resource utilization appears to be complex and varies across the four procedures examined.

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Authors

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Introduction

The public health burden of disease related to obesity is rapidly increasing (1) and is associated with rising health care costs (2). Recent data indicates that nearly two thirds of Australian adults are overweight or obese (3). Obesity is also a risk factor for health conditions such as heart disease and diabetes (4).

Literature exploring the relationship between obesity and surgical outcomes is extensive. Obesity is a risk factor for post-operative complications (5), longer operating times (6), and increased hospital costs (7). Obese patients represent a diagnostic challenge for the surgeon (8), and require additional surgical preparation (9), and time to assess anaesthetic and operative risks (10). Bariatric equipment and supplementary staff may also be necessary (11).

However, the relationship between obesity and outcomes is variable and complicated by the type of procedure performed and surgical approach used (12). One retrospective review of patients undergoing total hip replacement (THR) reported a 5% higher cost for every 1 unit increment of Body Mass Index (BMI) above 30 kg/m^2 (13). In another study a BMI greater than 30 kg/m^2 was associated with higher rates of infection and venous thromboembolism (14). In contrast, obesity was not associated with worse outcomes in patients undergoing THR (15). Evidence about the impact of obesity on outcomes in other common surgical procedures, such as appendectomy, cholecystectomy and hysteroscopy (16) is also conflicting (17-19) or limited to a small study cohort (20).

Given the discrepancies in the evidence, we chose to explore this further in four frequently performed surgical procedures in one Australian tertiary referral hospital. These procedures were laparoscopic appendectomy (APP); laparoscopic cholecystectomy and intraoperative cholangiogram (CHOLE); THR; and hysteroscopy with dilation and curettage (DC). The specific objectives of the study were (i) to determine the prevalence of overweight and obesity in the cohort of surgical patients chosen and (ii) to evaluate the association between BMI and resource utilisation outcomes (procedural duration, anaesthetic duration, intensive care stay, total hospital stay and cost) in these surgical procedures.

Methods

This retrospective cohort study included patients undergoing four surgical procedures at a regional tertiary referral hospital between 01 January 2016 and 31 December 2016. This hospital is the major acute care hospital in a regional Health District and performs approximately 13 000 surgical procedures per year. (21). Ethical approval for the study was obtained from the joint Illawarra Shoalhaven Local Health District (ISLHD) / University of Wollongong Human Research Ethics Committee (HE2017/370).

Data was obtained from the Illawarra Health Information Platform (IHIP), a non-identifiable health databank and health records linkage system (22). Data included admitted patient data, electronic medical record extracts, operating theatre data and cost data. Procedural duration was time from placement on the operating table to final dressings were applied. Anaesthetic duration was time from arrival in the anaesthetic waiting bay to arrival in the post anaesthetic care unit. Australian Government definitions (23) for overweight and obesity were used to stratify patients, with underweight defined as BMI <18 kg/m^2; a healthy weight BMI 18.5-

24.9 kg/m^2; overweight BMI of 25-29.9kg/m$^{2\,;}$ and obesity BMI > 30 kg/m$^{2.}$ Information included in the supplementary tables defines Class I obesity as BMI 30-34.99 kg/m$^{2;}$ Class II as BMI 35-39.99 kg/m$^{2;}$ and Class III obesity as a BMI >40 kg/m$^{2.}$

Eligible patients for the study were identified using the Australian Classification of Health Intervention Codes (ACHI) (24) of: laparoscopic appendectomy (ACHI code 30572-00 [926]); laparoscopic cholecystectomy and intraoperative cholangiogram (ACHI code 30445-00 [965]); total hip replacement (ACHI codes 48318-00 and 49319-00 [1489]); and hysteroscopy with dilation and curettage (ACHI code 35640-00 [1265]). Inclusion criteria were all non-pregnant adults over 18 years of age that had undergone one of the four surgical procedures of interest under general anaesthesia. Exclusion criteria were patients in whom multiple procedures were performed or individuals with incomplete BMI data.

Cost data was obtained from the Activity Based Management portal (25). Costs included the total cost, medical, nursing, allied health, imaging, operating room, pathology, critical care, on costs, non-clinical, pharmacy, excluded, specialist procedure suite, prosthetics, and ward supply costs for each episode of care. The five highest cost categories were reported in addition to total cost.

All statistical analysis was undertaken using SPSS version 24.0 (IBM, Armonk, New York, USA). Normality was assessed using the Shapiro Wilk test. Non-normally distributed data are reported as median and interquartile range. A binomial test was used to compare prevalence of overweight and obesity in the study cohort with local (26) and national population prevalence estimates (3). Associations between categorical variables were evaluated using the

Chi Square test. Differences between groups (e.g. BMI categories) were analysed using the Kruskal Wallis tests for continuous variables. Hierarchical linear regression was used to assess the association between BMI and the outcomes of LOS, operative and anaesthetic duration and all cost categories. Standardised beta coefficients and the 95% confidence interval are reported for each model after controlling for potential confounders of age, gender and comorbidities (measured using the Charlson Comorbidity Index score (27). All statistical tests were two-sided, with a p value of 0.05 considered statistically significant.

Results

A total of 1098 individuals were identified. The number of eligible individuals with missing BMI data was 399 (36.3%). The proportion with missing data varied from 2.4% (THR, n=4); 7.8% (D&C, n=12); 42.5% (CHOLE, n=152); 55.1% (APP, n=231). The main reason for missing BMI data was omission of a height measurement. The mean weight in the individuals with missing BMI data was 76.1 kg (APP group); 108.7 kg (D&C); 81.8 kg (CHOLE) and 91.3kg (THR). This was not substantially different from the mean weight of included individuals. There were also no significant differences between excluded and included participants for gender or LOS. However, those with missing BMI data in the APP group were significantly younger ($p<0.0001$).

The final study population consisted of 699 individuals. Males comprised approximately half of patients undergoing APP (48.4%) and THR (49.7%), The median (IQR) age of individuals ranged from 34 years (IQR: 24-48) for APP; to 70 years (IQR: 59-78) for THR. In the APP group, there were significant differences in age between the BMI categories (Table S1, $p=0.001$).

The proportion of surgical patients who were overweight ranged from 85.9% (THR group) to 57.4% (APP group). The proportion who were obese varied from 27.7% (APP group) to 53.4% (CHOLE group) (Table 1). Very few patients were underweight.

BMI was not associated with worse outcomes in any of the four surgical procedures (Table 2). Underweight individuals were excluded from the costing analysis as they comprised less than five individuals in each cohort. Individuals who were overweight or obese did not cost significantly more than normal weight individuals in any surgical group (Table S2).
After controlling for the effects of age, gender and comorbidities there was a significant positive association between BMI and LOS (Table S3, $p<0.05$), medical costs and allied health costs for the APP group. For those who underwent CHOLE, there was also a significant positive association between BMI and critical care costs ($p<0.0001$).

In contrast, there was either no association or a negative association between BMI and outcomes in the other types of surgical procedures studied. For example, in the THR group, a high BMI was associated with shorter LOS, and lower total costs and medical costs. There was also a significant negative association between BMI and nursing costs in those undergoing DC, CHOLE and THR (Table S3).

Discussion

The high prevalence of overweight and obesity in the Australian community (3) was reflected in the present study. A high proportion of individuals were overweight or obese at the time of surgery. However, BMI was not associated with increased hospital resource utilisation in any of the four surgical procedures examined after controlling for age, gender and complexity. For other outcomes of hospital resource utilisation, such as total length of stay and cost, the relationship appears to be more complex, and outcomes were inconsistent across the four procedures examined in this study.

The prevalence of obesity in our surgical sample was also significantly higher than local (26) and national (3) population prevalence estimates for all procedures except appendectomy. This is consistent with evidence that obesity is associated in the pathophysiology of the development of cholelithiasis (28), arthropathies (29)**,** and gynaecological bleeding (30), but not appendicitis (31). This is also consistent with previous research on obesity in surgical populations. For example, the prevalence of obesity in those requiring THR or total knee replacement was significantly greater than the general population (29)**.** These findings were supported in another study that reported substantial increases in the prevalence of obesity [increasing from 14.9% to 20.6% (p <0.001)] and morbid obesity [increasing from 7.1% to 14.8% (p <0.001)] among surgical patients between 1989-1991, compared to those whose procedure occurred between 2006-2008 (32).

Several findings were in contrast to the broader literature. For example, a high BMI in the current study was associated with lower hospital costs in some procedures (e.g. patients undergoing THR, CHOLE or DC). These findings are not consistent with previous research which suggests that obesity is associated with increased costs in a range of surgical procedures, including those examined in this study (33). Of note, in one of the largest studies to date, Mason et al (34) conducted an analysis of more than 2 million non-bariatric surgical procedures and reported that obesity was associated with a significant increased LOS (34). The findings in the present study regarding the cost of appendectomy is much lower than the cost found in a recent Australian study (35). This may represent greater efficiencies due to a dedicated acute surgical unit.

Reasons for the inconsistency of association between BMI and outcomes in the four surgical procedures examined in this study are not clear. This may be due to variations in the data collection systems used. Inconsistencies in the definitions used by coders for anaesthetic and surgical duration are also possible. Similarly, procedure times may not include delays before and during an operation that can be variable and operator dependent.

Documenting the overrepresentation of obesity in the surgical population is highly important from a pragmatic perspective. Obese patients require more extensive care, including bariatric equipment and additional staff time to assist with peri-operative care (36). Future research to explore the relationship between BMI and outcomes in other surgical procedures is needed. In addition, recording patient complexity, and stricter measures of anaesthetic and procedural duration would be beneficial. Longitudinal analyses with larger sample sizes exploring one procedure may also be informative. Recording patient resource consumption may help explain relative differences in patient expenses and may facilitate benchmarking.

Given the high prevalence of obesity in the surgical populations, public discussion regarding appropriate weight management options warrants consideration. This includes strategies such as perioperative rehabilitation, bedside motivational interviewing, team care arrangements and linkage with dietetics to facilitate behavioural change. Unless the issues associated with obese patients are addressed, obese patients will continue to experience worse health outcomes including post-operative complications (37).

This study also suggests that being underweight rather obese may be more problematic for some surgical procedures. For instance, those who were underweight and had a THR in the present study had an increased mortality rate (data not shown), and higher total costs associated with their care (p=0.02, data not shown). However our patient numbers were very small (n = <5 in each surgical group). Further investigation with larger cohorts of underweight patients may be of value. Previous studies indicate that underweight patients have poorer outcomes compared to those with a healthy BMI (12). Some of the reasons for worse outcomes in underweight patients include; deconditioning, malnutrition, low preoperative haemoglobin and poor baseline status (38, 39). The poorer outcomes and higher costs may also be related to the high prevalence of malnutrition in older patient populations who present for THR, especially among those who present after a fall or with a fractured neck of femur (40). Guidelines to counsel underweight or malnourished patients to improve nutritional status prior to surgery may be of benefit in this vulnerable population.

This study has several strengths including completeness of the data regarding BMI for the THR and D&C procedures surgical and anaesthetic duration times, costs, and use of the Charlson index score to describe complexity of the patients. However, there are limitations. This includes excluding 55.1% and 42.5 % of the appendectomy and cholecystectomy study population due to missing BMI data. This may have potentially introduced a selection bias. The relatively small sample in each of the four surgical cohorts analysed in this study may also limit generalisability. We were unable to extract the American Society of Anaesthesiologists physical classification scores to stratify patients according to disease burden (41) and the technical difficulty of the surgery for a significant portion of patients, making it difficult to account for relative patient complexity as commonly reported in previous studies (34, 42). The impact of unmeasured variables, such as procedural and anaesthetic delays, and variation in operator experience and perioperative delays on operating times were not recorded, and all of these are possible confounding variables. The proportion of elective surgeries varied between surgical types and this may have also had a bearing on outcome parameters. Postoperative complications and readmissions were also not recorded in the data set examined. The study is cross sectional in nature and further research from a longitudinal perspective is warranted. Another important limitation is that it was difficult to compare costs of surgery locally with international studies due to variations in the funding models used to calculate cost and charges for the different procedures.

CONCLUSION

This study highlights the high prevalence of overweight and obesity among patients undergoing four common surgical procedures. Our findings suggest that overweight and obesity are not consistently associated with worse outcomes and higher costs among patients undergoing these procedures. The only procedure in the current study associated with a longer length of stay and higher medical and allied health costs after adjusting for age, gender and patient complexity was appendectomy. Since the opposite appeared to be apparent for the other procedures, further research into these areas is warranted.

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Table S1. Descriptive characteristics according to procedure and BMI category.

	Underweight BMI<18.5 kg/m^2	**Healthy weight BMI 18.5-24.99 kg/m^2**	**Overweight BMI 25-29.99 kg/m^2**	**Obese class I BMI 30-34.99 kg/m^2**	**Obese class II BMI 35-39.99 kg/m^2**	**Obese class III BMI >40 kg/m^2**	**Total**	**P value**
Appendectomy								
Number (%)	#	78 (41.5)	54 (28.7)	27 (14.4)	15 (8.0)	10 (5.3)	188	--
Males n (%)	#	36 (39.6)	25 (27.5)	16 (17.6)	6 (6.6)	6 (6.6)	91 (48.4)	0.78
Age (years)	31.5 (21-62.3)	27 (21-39)	35 (27-50.3)	37 (30.8-48.8)	40 (22.5-58.3)	49.5 (39.8-70.8)	34 (24-48)	0.001
Weight (kg)	53 (51-54.8)	64 (57-73)	80 (72-85.3)	91 (88-99.6)	102 (91.6-121.2)	115 (110.7-127.4)	76 (64.7-90)	-
Hysteroscopy with dilatation and curettage								
Number (%)	#	36 (25.4)	25 (17.6)	24 (16.9)	23 (16.2)	31 (21.8)	142	-
Males (n/%)	#	0	0	0	0	0	0	-
Age (years)	43 (19.7-43.8)	44.5 (35.4-58.2)	47 (32-55)	54.5 (44.4-67.2)	55 (41.7-61.8)	47 (39.5-54)	47.5 (37.9-60)	0.08
Weight (kg)	39 (36.5-56)	59 (55.2-63.8)	71.2 (69-75.6)	85.5 (78.5-92.6)	98 (84.1-107.2)	120 (115-129)	80 (66.4-108)	-
Laparoscopic Cholecystectomy								
Number (%)	0	30 (14.6)	66 (32)	46 (22.3)	26 (12.6)	38 (18.4)	206	-
Males (n/%)	0	10 (16.8)	26 (33.8)	15 (19.5)	5 (6.5)	21 (27.3)	77 (37.3)	0.05
Age (years)	0	50.5 (32-76.1)	58 (39.9-73)	57 (39.8-78)	46 (36-69.1)	56 (43.6-73)	55 (38-73.1)	0.57

Weight (kg)	0	65 (58-73.4)	77 (70-85.1)	86 (80-101.2)	102 (91.3-123)	120 (115.8-127.5)	84 (73.6-105)	-
Total Hip Replacement								
Number (%)	#	21 (12.9)	62 (38)	42 (25.8)	24 (14.7)	12 (7.4)	163	-
Males (n/%)	#	10	34 (42)	18 (22.2)	15 (18.5)	4 (4.9)	81 (49.7)	0.28
Age (years)	82 (76-88)	62 (53-75.7)	70 (58.9-76)	67.5 (60.8-80.1)	71 (57.7-78)	74 (71-80)	70 (59-78)	0.13
Weight (kg)	53.6 (49-58.1)	64.5 (57-75)	78.2 (72.4-84.2)	93 (82.3-99.9)	101 (95.7-110.1)	115.5 (107.8-137.2)	85 (74.8-97.8)	-

Data suppressed due to cell size < 5

Table S2. Unadjusted median costs (2016 $AUD) between normal weight, overweight and obese patients for four surgical procedures

Item costs, $AUD median (IQR)	Normal weight (BMI 18.5-24.9 kg /m^2)	Overweight (BMI 25-29.99 kg /m^2)	Obese (BMI >30 kg /m^2)	P value
Appendectomy				
Medical	621 (466-920)	432 (342-661)	910 (605-1430)	0.02
Nursing	578 (356-849)	554 (352-878)	604 (401-1000)	0.61
Allied	3.2 (1.4-9.7)	2.1 (1.0-5.3)	7.8 (2.0-13.4)	0.009
Operating Room	2510 (1878-3337)	2491 (1881-3433)	2821 (2242-3918)	0.41
Total Cost	5504 (4191-7585)	5585 (4112-8383)	6527 (5236-9162)	0.01
Hysteroscopy with dilatation and curettage				
Medical	70 (50-216)	59 (45-105)	70 (53-126)	0.82
Nursing	114 (73-319)	80 (54-140)	96 (73-152)	0.49
Allied	0.4 (0.1-0.7)	0.2 (0.1-0.5)	0.3 (0.1-0.5)	0.55
Operating Room	1456 (1205-2132)	1288 (940-1553)	1367 (1088-1749)	0.56
Total Cost	2093 (1910-4048)	1765 (1522-2577)	1966 (1633-2527)	0.49
Laparoscopic Cholecystectomy				
Medical	1259 (498-2180)	1090 (567-2153)	880 (505-1773)	0.14
Nursing	1559 (875-2937)	1488 (765-2470)	1188 (673-1987)	0.08
Allied	9.6 (4.3-43.3)	10.2 (2.6-139.6)	12.8 (5.4-47.8)	0.31
Critical Care	0 (0-0)	0 (0-0)	0 (0-0)	0.88
Operating Room	3570 (2732-5277)	3777 (2960-4838)	3757 (2861-5025)	0.91
Total Cost	10979 (6070-16126)	8670 (6105-13135)	8281 (6288-11929)	0.84
Total Hip Replacement				
Medical	1143 (852-1771)	1100 (860-1563)	1058 (828-1549)	0.62
Nursing	1518 (1216-2362)	1543 (1175-2312)	1460 (1137-2183)	0.92
Allied	817 (632-1048)	832 (667-975)	762 (616-948)	0.31
Operating Room	4538 (3464-6387)	4411 (3413-5222)	4463 (2992-5182)	0.95
Total Cost	19738 (16627-21299)	18253 (16476-20928)	17936 (1495-20505)	0.08

Costs for critical care not included for appendectomy, hysteroscopy with dilatation and curettage, and total hip replacement as there were no critical care stays.

Table S3. Standardized regression coefficients for hierarchical regression analyses evaluating the association between BMI and various outcomes.

All analyses are adjusted for age, gender, and patient complexity measured using the Charlson Comorbidity Index score.

	Appendectomy	D&C	Laparoscopic cholecystectomy	THR
	standardized B coefficient	standardized B coefficient	standardized B coefficient	standardized B coefficient
Length of stay	0.053**	-0.072*	-0.163	-0.15*
Anaesthetic duration	0.028	0.051	0.066	-0.096
Procedure duration	0.128	-0.09	0.008	-0.113
Hours in ICU	N/A	N/A	0.016	N/A
Costs				
Total	0.11	-0.13	-0.016	-0.121**
Medical	0.18**	-0.135	-0.196*	-0.103**
Nursing	0.096	-0.128**	-0.167*	-0.105*
Allied health	0.096**	-0.095**	-0.122	-0.147
Critical care	0.046	N/A	0.026*	N/A
Operating room	0.06	-0.069	-0.019	-0.046

*=p<0.0001; ** p<0.05; N/A: not applicable as no hours in critical care / ICU