Royal Australasian College of Surgeons

Days alive and out of hospital after laparoscopic cholecystectomy

Harry Alexander,* Matthew Moore,* Jacqueline Hannam,* Garth Poole,† Adam Bartlett† and Alan Merry*

*Department of Anaesthesiology, Faculty of Medical and Health Sciences, University of Auckland, Grafton, New Zealand and
†Department of Surgery, Faculty of Medical and Health Sciences, University of Auckland, Grafton, New Zealand

Key words
cholecystectomy, gallstones, outcome, quality.

Correspondence
Dr Harry Alexander, Faculty of Medical and Health Sciences, University of Auckland, Grafton 1023, New Zealand.
Email: hale087@aucklanduni.ac.nz

H. Alexander MBChB, BMSc (Hons);
M. Moore BE, PhD; **J. Hannam** BSc, (Hons) PhD;
G. Poole MBChB, FRACS; **A. Bartlett** FRACS, PhD; **A. Merry** FANZCA, FFPMANZCA.

Accepted for publication 23 September 2022.

doi: 10.1111/ans.18099

Abstract

Background: Days alive and out of hospital (DAOH) is a metric that incorporates several outcomes into a single, standardized measure. This study aimed to explore the utility of DAOH in assessing the outcomes of a retrospective cohort of patients undergoing laparoscopic cholecystectomy (LC).

Methods: Patients undergoing LC at Auckland City Hospital between 1 January 2010 and 31 August 2015 were included. DAOH values were calculated for the 90 days from the date of surgery ($DAOH_{90}$) and described using median and interquartile ranges (IQR). $DAOH_{90}$ distributions were compared using a two-tailed (non-parametric) Wilcoxon-Mann–Whitney test.

Results: 1652 patients undergoing LC were studied. Patients experiencing complications ($n = 70$, 4.2%) had fewer $DAOH_{90}$ (median 83, IQR 79, 86) than patients who underwent uncomplicated LC (median 88, IQR 86, 88), $P < 0.001$. Patients who were converted to open cholecystectomy ($n = 70$, 4.2%) also had fewer $DAOH_{90}$ (median 82.5, IQR 79, 84) than patients who underwent uncomplicated LC, $P < 0.001$. Post-operative complications and conversion had a statistically significant effect on $DAOH_{90}$ at each of the tested quantiles, except for conversion at the 0.1 quantile.

Conclusion: $DAOH_{90}$ is readily calculable from existing New Zealand administrative data sources and is sensitive to the occurrence of complications after LC.

Introduction

Outcome measurement is an important component of quality assessment in surgery. Surgical trials and outcome studies have historically focused on a variety of adverse events, or complications, which may occur peri-operatively.[1] These outcomes are inconsistently measured and often provide limited insight into the perioperative experience.[2,3] In low risk surgery, such as laparoscopic cholecystectomy (LC), major complications occur too infrequently to detect meaningful differences in surgical performance, given the numbers of procedures typically undertaken by individual surgeons and even by entire surgical units.[4]

Patient reported outcome (PRO) measures (PROMs) measure the impact of surgery on patients' quality of life and are increasingly used as end-points in clinical trials.[5] For LC, current measurement of PROs is focused on short-term outcomes, such as pain and nausea, which capture only part of the peri-operative experience, and are only of short-term significance.[6] Measurement of PROs also requires administration of questionnaires which may be time consuming and expensive.[7]

Recent systematic reviews have identified significant heterogeneity in the measures used to evaluate the outcomes of LC,[3,6] which limits the ability to draw meaningful conclusions from studies.[8] There is growing consensus that standardized outcome measures should be used across surgical trials and outcome studies.[2] Despite the large number of measures reported in studies, few provide an overall assessment of the outcome of surgery.[9]

Days alive and out of hospital (DAOH) is an emerging metric that incorporates several clinically relevant outcomes into a single, standardized measure. It has been used in patients with heart failure[10,11] and in a small number of surgical contexts.[9,12] DAOH may be a useful measure for low-risk surgical procedures because it amalgamates the effects of several clinical outcomes (length of stay, readmission and mortality) into a single, objective, continuous outcome measure.

In New Zealand, national datasets offer the opportunity to gather the data needed to calculate DAOH for large numbers of patients at low cost.[13] Validation data have recently been published for DAOH in a large cohort of Canadian patients undergoing major elective surgery[12] and for a similar measure, 'Days at Home', in an Australian surgical cohort.[9] A recent study by our group measured DAOH in surgical patients before and after implementation of the World Health Organization surgical safety checklist at Auckland City Hospital.[13] However, the utility of these measures in evaluating the outcomes of low-risk surgical patients, such as those undergoing LC, has not yet been explored.

Therefore, we aimed to test the hypotheses that patients undergoing LC who suffer complications or conversion to open cholecystectomy would have a lower number of $DAOH_{90}$ than those who do not.

Methods

This study was registered prior to the start of data collection (ACTRN12617000180314). The study was approved by the Northern A Health and Disability Ethics Committee (17/NTA/119/AM01) and the Auckland District Health Board (ADHB) Research Review Committee (A+7394).

Data sources

Data were obtained from the Ministry of Health-held National Minimum Dataset (NMDS) and the ADHB-held otago clinical audit (OCA). The NMDS is a collection of hospital discharge information for patients treated in New Zealand. Admissions data are routinely collected for all inpatients and day stay patients treated in New Zealand public or private healthcare facilities.

The OCA is a prospectively maintained database held by the Department of General Surgery at ADHB. These data are routinely coded from clinical records by the surgical unit at the time of patient discharge and include patient demographics, peri-operative information and post-operative outcomes.

Patient selection

All adult (>18 years) patients undergoing elective or acute LC (with or without conversion to open cholecystectomy) at Auckland City Hospital between 1 January 2010 and 31 August 2015 were eligible for inclusion in this study. The end date differed from that registered (1 January 2010 to 31 December 2015), as there was a poor match between data sources towards the end of the data set.

Patients meeting inclusion criteria were identified from the NMDS using ICD-10 codes for laparoscopic cholecystectomy (with or without cholangiogram) and cholecystectomy (conversion is coded as such). NMDS data were matched with OCA data using encrypted patient National Health Index (NHI) and an overlap between operation date recorded by the NMDS and admitted period as recorded by the OCA. Patients with missing or incomplete OCA data, or patients with an incomplete match, were excluded from the study.

Data collection

Admissions and mortality data were obtained from the NMDS. Perioperative data were obtained from the OCA. Demographic (age, gender, ethnicity) and comorbidity (ASA) data were also collected. Post-operative data included clinical complications and their severity (minor, intermediate, severe).

Calculation of DAOH

$DAOH_{90}$ values were calculated using R in RStudio using admissions and mortality data obtained from the NMDS.[14] $DAOH_{90}$ values were calculated for 90 days from the date of index LC, as recorded in the NMDS. $DAOH_{90}$ was calculated as 90 minus the number of days the patient spent as an inpatient in any New Zealand healthcare facility, and also minus the number of days (if any) that the patient was dead.[13] The maximum $DAOH_{90}$ was 89, as each patient undergoing an operation spent at least 1 day in hospital (range – 0 to 89 $DAOH_{90}$).

Statistical analysis

Patients were divided into four groups; uncomplicated LC, LC with post-operative complication, LC converted to open cholecystectomy, and LC converted to open (with additional complication). The relationship between the occurrence of complications and $DAOH_{90}$ values was examined by comparing the distribution of $DAOH_{90}$ values in different patient groups.

The distribution of DAOH is typically left-skewed with a small secondary peak at 0 DAOH.[9] The distribution of $DAOH_{90}$ values was described using median and interquartile ranges (IQR). Statistical significance of differences between distributions was determined using the two-tailed (non-parametric) Wilcoxon-Mann–Whitney (WMW) test, and the effect of patient and clinical factors assessed using quantile regression.

Results

From the NMDS 2144 potentially eligible operations were identified; 491 patients (22.9%) were unable to be matched to the OCA, and one further patient was excluded for missing ASA Physical Status, resulting in a total of 1652 patients (77.1%).

Patient demographics

A summary of the demographic and case-mix information of the patients is shown in Table 1. Seventy patients (4.2%) experienced complications after LC. A further 70 patients (4.2%) were converted to open cholecystectomy, 22 (1.3%) of whom experienced an additional post-operative complication. 1512 (91.5%) patients had a complication-free LC. In-hospital mortality was zero in our final sample, though one case of in-hospital mortality recorded in the NMDS could not be matched to the OCA. There were four cases of death within 30 days (0.2%), and six cases within 90 days (0.4%).

Table 1 Patient demographics, ASA score and timing of surgery overall, and by presence/absence of conversion and complication

	Laparoscopic		Converted		Overall
	No complications (*N* = 1512)	With complications (*N* = 70)	No complications (*N* = 48)	With complications (*N* = 22)	(*N* = 1652)
Age (years)					
Median (IQR)	47.7 (34.3, 60.5)	58.2 (47.0, 70.4)	57.4 (41.0, 71.0)	62.0 (49.7, 71.2)	48.7 (35.0, 61.3)
Age group (years)					
18–39	531 (35.1%)	12 (17.1%)	12 (25.0%)	3 (13.6%)	558 (33.8%)
40–59	585 (38.7%)	27 (38.6%)	14 (29.2%)	5 (22.7%)	631 (38.2%)
60–79	355 (23.5%)	25 (35.7%)	21 (43.8%)	11 (50.0%)	412 (24.9%)
80+	41 (2.7%)	6 (8.6%)	1 (2.1%)	3 (13.6%)	51 (3.1%)
Gender					
M	441 (29.2%)	32 (45.7%)	27 (56.3%)	13 (59.1%)	513 (31.1%)
F	1071 (70.8%)	38 (54.3%)	21 (43.8%)	9 (40.9%)	1139 (68.9%)
Ethnicity					
Māori	154 (10.2%)	5 (7.1%)	5 (10.4%)	4 (18.2%)	168 (10.2%)
European	817 (54.0%)	39 (55.7%)	28 (58.3%)	12 (54.5%)	896 (54.2%)
Pacific peoples	169 (11.2%)	13 (18.6%)	6 (12.5%)	0 (0%)	188 (11.4%)
Asian	302 (20.0%)	11 (15.7%)	9 (18.8%)	5 (22.7%)	327 (19.8%)
Other	70 (4.6%)	2 (2.9%)	0 (0%)	1 (4.5%)	73 (4.4%)
ASA					
1	646 (42.7%)	15 (21.4%)	16 (33.3%)	1 (4.5%)	678 (41.0%)
2	718 (47.5%)	34 (48.6%)	23 (47.9%)	13 (59.1%)	788 (47.7%)
3	143 (9.5%)	21 (30.0%)	9 (18.8%)	7 (31.8%)	180 (10.9%)
4	5 (0.3%)	0 (0%)	0 (0%)	1 (4.5%)	6 (0.4%)
Timing					
Arranged	971 (64.2%)	47 (67.1%)	25 (52.1%)	12 (54.5%)	1055 (63.9%)
Urgent	405 (26.8%)	19 (27.1%)	10 (20.8%)	8 (36.4%)	442 (26.8%)
Emergency	136 (9.0%)	4 (5.7%)	13 (27.1%)	2 (9.1%)	155 (9.4%)

Table 2 Median (IQR) $DAOH_{90}$ by patient demographics, ASA score and timing of surgery overall, and by presence/absence of conversion and complication

	Laparoscopic		Converted		Overall
	No complications	With complications	No complications	With complications	
Overall	88 (86, 88)	83 (79, 86)	83.5 (81.75, 85)	77.5 (68.75, 81)	88 (86, 88)
Age group (years)					
18–39	88 (87, 88)	85 (84.25, 87)	83 (81.75, 85)	82	88 (86, 88)
40–59	88 (87, 88)	83 (79, 85.5)	84.5 (83.25, 85)	81 (73, 82)	88 (86, 88)
60–79	87 (86, 88)	82 (79, 84)	83 (79, 84)	76 (62, 80.5)	87 (84, 88)
80+	86 (84, 88)	82.5 (74.75, 86.5)		71	86 (83, 87.5)
Gender					
M	88 (86, 88)	83 (78.5, 86)	83 (81, 84)	76 (68, 81)	87 (85, 88)
F	88 (86, 88)	83 (80.25, 85.75)	84 (83, 85)	79 (71, 82)	88 (86, 88)
Ethnicity					
Māori	88 (87, 88)	82 (81, 86)	84 (84, 85)	80	87 (86, 88)
European	88 (86, 88)	83 (79, 85)	83.5 (82.75, 84.25)	76 (68, 81.25)	88 (85.75, 88)
Pacific peoples	88 (86, 88)	82 (76, 86)	83.5 (83, 85.5)		87 (86, 88)
Asian	88 (87, 88)	83 (80, 85.5)	80 (78, 85)	73 (56, 80)	88 (86, 88)
Other	88 (87, 88)				88 (87, 88)
ASA					
1	88 (87, 88)	83 (81.5, 86)	84.5 (83.75, 85)		88 (86.25, 88)
2	88 (86, 88)	83.5 (79.25, 85)	83 (81, 84)	80 (71, 82)	87 (86, 88)
3	86 (84, 88)	81 (76, 85)	84 (78, 84)	71 (62, 74.5)	86 (82, 88)
4	82 (82, 84)				82 (77.5, 83.5)
Timing					
Arranged	88 (87, 88)	84 (80, 86)	84 (82, 85)	79.5 (72.5, 81.25)	88 (86, 88)
Urgent	87 (86, 88)	82 (78, 85)	84 (83, 84)	73.5 (68, 81.25)	87 (86, 88)
Emergency	87 (86, 88)	79	83 (80, 84)		87 (85, 88)

Complications

Patients who had complications after LC had a median (IQR) 83 (79, 86) $DAOH_{90}$ (see Table 2). Patients who had uncomplicated LC had a median 88 (86, 88) $DAOH_{90}$. The difference in these distributions was statistically significant ($Z = 11.0$, $P < 0.001$; Fig. 1).

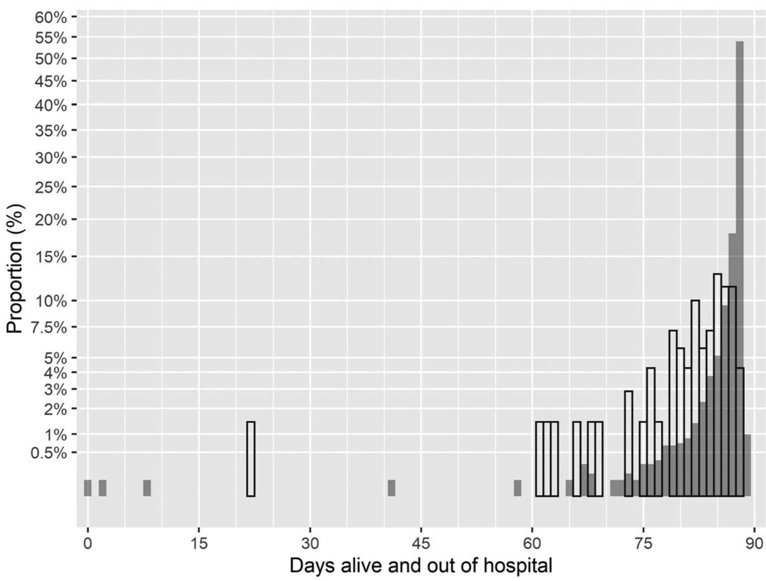

Fig. 1. DAOH values for LC (with and without post-operative complications). The number of patients (*y*-axis) for each $DAOH_{90}$ value (*x*-axis) is shown. The *y*-axis has been transformed using the square root function. The distribution of $DAOH_{90}$ values was compared between these two groups using the WMW test ($Z = 11.0$, $P < 0.001$). Complications: ■: no; □: yes.

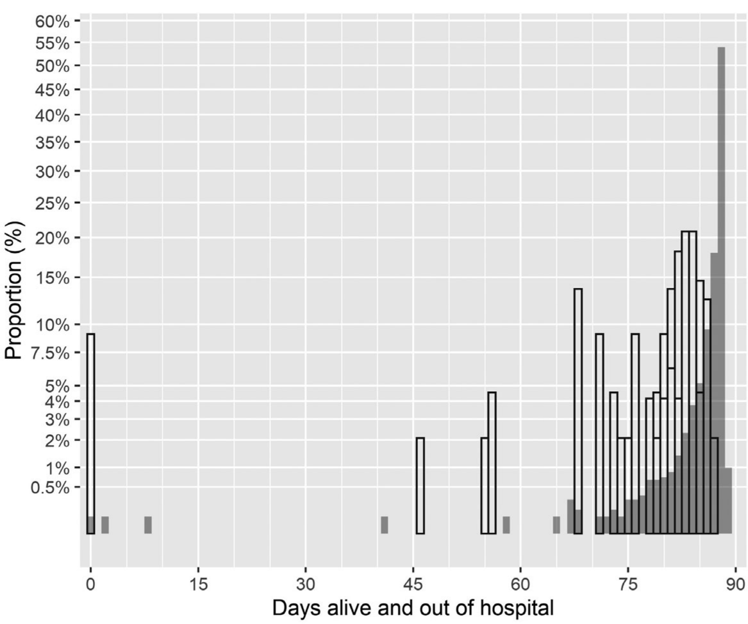

Fig. 2. DAOH values for patients undergoing conversion to open cholecystectomy versus complication-free LC. The number of patients (*y*-axis) with any given $DAOH_{90}$ value (*x*-axis) is shown. The *y*-axis has been transformed using the square root function. The distribution of $DAOH_{90}$ values was compared between these two groups using the WMW test ($Z = 12.8$, $P < 0.001$). Group: ■: complications-free LC; □: converted to open

Conversion from laparoscopic to open technique

Patients who underwent conversion to open cholecystectomy (with or without additional post-operative complication) had a median (IQR) 82.5 (79, 84) $DAOH_{90}$. This distribution was significantly different from the complication-free LC group ($Z = 12.8$, $P < 0.001$; Fig. 2).

Patients who were converted to open cholecystectomy and experienced a post-operative complication had a median (IQR) 77.5 (68.75, 81) $DAOH_{90.}$ This distribution was significantly different from the group of patients who were converted open cholecystectomy but did not experience an additional post-operative complication, who had a median (IQR) 83.5 (81.75, 85) $DAOH_{90}$ ($Z = 4.6$, $P < 0.001$; Fig. 3).

Regression analysis

Multi-variate quantile regression analysis was conducted, with DAOH as the predictor at 0.1, 0.25 and 0.5 (i.e. median) quantiles (Table 3). Complications and conversion had a statistically significant ($P < 0.001$) effect on $DAOH_{90}$ at each of the tested quantiles, except for conversion at the 0.1 quantile. Age and ethnicity did not have a substantial impact on $DAOH_{90}$ after LC, accounting for other factors. Small cell sizes influenced the fit of the regression models, with high residuals particularly at lower quantiles (refer to Fig. 4).

Discussion

This study has demonstrated that $DAOH_{90}$ is sensitive to the occurrence of complications after LC. This work has also confirmed that

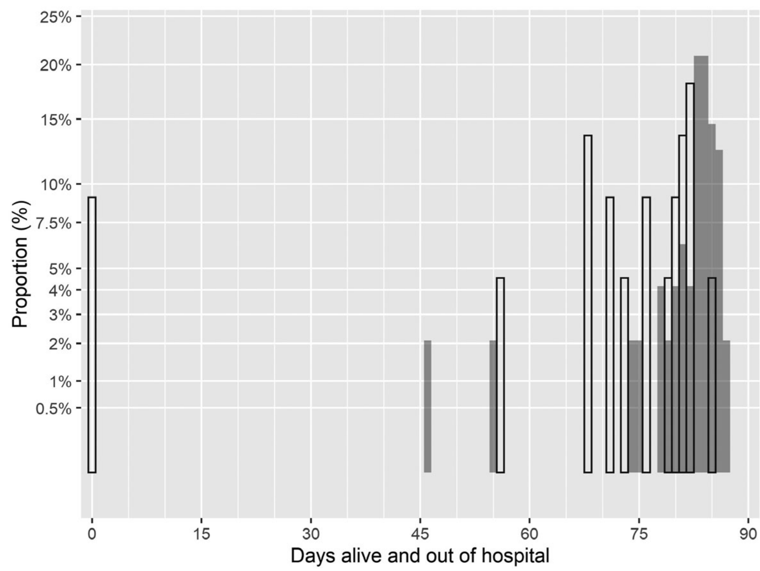

Fig. 3. DAOH values for patients undergoing conversion to open cholecystectomy, with or without additional complication. The number of patients (*y*-axis) with any given $DAOH_{90}$ value (*x*-axis) is shown. The *y*-axis has been transformed using the square root function. The distribution of $DAOH_{90}$ values was compared between these two groups using the WMW test (Z = 4.6, *P* < 0.001). Complications: ■: no; □: yes.

Table 3 Results of multivariable quantile regression analysis with $DAOH_{90}$ as the outcome at 0.1, 0.25 and 0.5 (i.e., median) quantiles

	0.1		0.25		0.5	
Complications	−14.00***	(−18.60, −9.40)	−8.00***	(−9.60, −6.40)	−4.78***	(−7.34, −2.22)
Conversion	−5.00	(−11.30, 1.30)	−5.00***	(−6.92, −3.08)	−4.00***	(−5.46, −2.54)
Age 40–59 (vs. 18–39)	1.00**	(0.29, 1.71)	0.00	(−0.54, 0.54)	0.00	(−1.17, 1.17)
Age 60–79 (vs. 18–39)	0.00	(−1.87, 1.87)	−1.00*	(−1.79, −0.21)	0.00	(−3.33, 3.33)
Age 80+ (vs. 18–40)	1.00	(−5.23, 7.23)	−1.00	(−2.52, 0.52)	−1.00	(−3.61, 1.61)
ASA2 (vs. ASA1)	−1.00**	(−1.70, −0.30)	0.00	(−0.52, 0.52)	0.00	(−0.85, 0.85)
ASA3 (vs. ASA1)	−5.00***	(−7.19, −2.81)	−2.00***	(−3.09, −0.91)	−1.00	(−2.08, 0.08)
ASA4 (vs. ASA1)	−11.00	(−33.38, 11.38)	−5.00	(−12.79, 2.79)	−4.00	(−8.04, 0.04)
Urgent (vs. elective)	0.00	(−0.75, 0.75)	0.00	(−0.49, 0.49)	−1.00	(−4.28, 2.28)
Emergency (vs. elective)	0.00	(−2.04, 2.04)	−1.00*	(−2.00, −0.00)	−1.00	(−2.83, 0.83)
European (vs. Maori)	−1.00*	(−1.80, −0.20)	0.00	(−0.59, 0.59)	0.00	(−1.46, 1.46)
Pacific (vs. Maori)	0.00	(−1.15, 1.15)	0.00	(−0.74, 0.74)	0.00	(−1.69, 1.69)
Asian (vs. Maori)	−1.00	(−2.01, 0.01)	0.00	(−0.79, 0.79)	0.00	(−1.56, 1.56)
Other (vs. Maori)	0.00	(−2.47, 2.47)	0.00	(−0.93, 0.93)	0.00	(−2.13, 2.13)

***$P < 0.001$;

**$P < 0.01$;

*$P < 0.05$.

Estimated effect sizes are given in $DAOH_{90}$, 95% confidence intervals are given in square brackets.

the data needed to calculate $DAOH_{90}$ can be readily obtained from routine admissions data in New Zealand. These findings are important because they have validated the use of $DAOH_{90}$ for surgical audit and benchmarking for LC in New Zealand.

Mortality, and many other peri-operative complications, occur too infrequently to be used to detect outlier surgical performance, particularly for low risk surgery such as LC.[15] By contrast, $DAOH_{90}$ encompasses the effects of several clinical outcomes into a single measure, and therefore provides a more sensitive, comprehensive and patient-centered measure of the peri-operative experience. Moreover, $DAOH_{90}$ is a standardized and objective outcome measure which does not rely on notes review or an adjudicator. By contrast, the detection of specific complications typically does depend on an adjudicator (in clinical trials) or on retrospective note review (in audits and outcome studies).

This retrospective study has demonstrated that DAOH is sensitive to the occurrence of post-operative complications in the context of LC. This reflects the fact that $DAOH_{90}$ is affected by length of stay (LOS) and by readmission to hospital, which would be influenced by complications.[16] Modest differences in LOS may not necessarily reflect the occurrence of complications but might instead be due to differences in discharge policy. However, there is considerable pressure on hospitals to minimize LOS for economic reasons, and for most patients a shorter LOS would probably be considered desirable. Isolated measurement and reporting of LOS is inappropriate because it may encourage the early discharge of patients.[17] By contrast, discharging patients too early might well result in increased likelihood of readmission to hospital, which would be captured by $DAOH_{90}$.[9]

There are several limitations to our analysis. First, the OCA data regarding complications are collected retrospectively and without the use of standardized definitions. These data are typically collected by registrars at the end of a patient's initial hospital admission. Complications which occur after discharge may be missed,

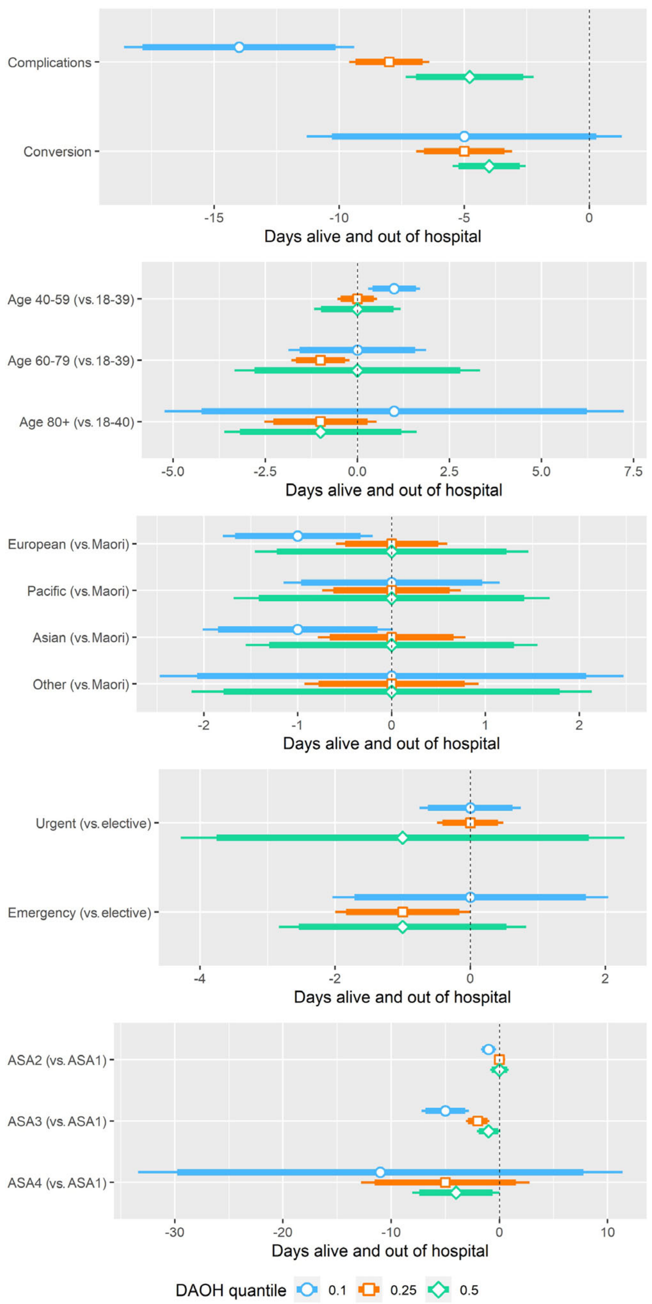

Fig. 4. Results of multivariable analysis with DAOH$_{90}$ as the outcome at 0.1, 0.25 and 0.5 (i.e. median) quantiles. Outlined shapes represent the estimate of the effect at separate quantiles of each predictor, with a thick bar indicating 90% confidence intervals and a thinner bar representing the 95% confidence intervals.

unless the patient is readmitted under the same team and the audit data are updated. Only 77% of patients identified from the NMDS could be matched with the OCA data. In unmatched cases, the OCA data were inaccurate or missing. It is possible that some bias was introduced to the analysis by the inability to include these patients.

The optimal timeframe for measurement of DAOH has not been established. Ninety days was chosen for this study, whereas Myles *et al*. proposed a timeframe of 30 days for their validation of 'days at home'.[9] Jerath *et al*. measured DAOH at 30, 90 and 180 days.[12] Lengthening the timeframe of DAOH would be expected to increase the sensitivity of this measure to late complications. This may be at the cost of specificity, particularly for low-risk procedures such as LC. It is possible that complications occurring towards the end of the 90-day period after LC are less likely to be related to the outcomes of the surgical procedure than they are to be related to the patient's underlying comorbidities. Conversely some complications from surgery may well manifest after 30 days or persist for longer than 30 days.

A variety of statistical approaches could be used to compare DAOH$_{90}$ values. In our study, DAOH$_{90}$ distributions were described by median, and compared using the WMW test. The WMW test was chosen because it is not dependent on a parametric distribution. Wasywich *et al*. reported mean DAOH$_{90}$ values in their study on patients with heart failure.[11] Comparison of mean DAOH$_{90}$ values relies on the central limit theorem to transform the data to a normal distribution.[18] Both Myles and Jerath *et al*. reported median values and used quantile regression model for adjusted comparisons between patient groups.[9,12]

In a recently published study from our group, Kruskal-Wallis tests were used to assess for differences between DAOH distributions.[13] Given the lack of prior comparable data for DAOH$_{90}$, it is hard to know at which quantile in the distribution of DAOH$_{90}$ a difference will manifest. With the low-risk group in this study the spike at zero which characterizes the results of higher risk groups (in which mortality is more than 0 and the impact of complications is often substantial) was missing, and the median appears to be a reasonable and straightforward choice.

Future research should focus on the application of DAOH$_{90}$ to larger cohorts and across different surgical procedures. The effect of various pre-operative risk factors on DAOH$_{90}$ should be explored, and a risk-adjustment model should be developed. The clinical importance of differences in DAOH$_{90}$ to patients, surgeons and funders should be studied. Future studies across multiple different New Zealand centres are required to determine whether DAOH$_{90}$ is comparable between centres. Multi-centre data would also facilitate the development of accurate benchmarks for DAOH$_{90}$ after LC in New Zealand patients. The choice of benchmark should vary according to case-mix and volume.

In conclusion, this study has demonstrated that DAOH$_{90}$ is sensitive to the occurrence of post-operative complications after LC. This standardized outcome measure is readily calculable from administrative databases in New Zealand and holds promise for use in surgical audit.

Funding information

This work was supported by the University of Auckland Honours Scholarship.

Acknowledgement

Open access publishing facilitated by The University of Auckland, as part of the Wiley - The University of Auckland agreement via the Council of Australian University Librarians.

Conflict of interest

None declared.

Author contributions

Harry Alexander: Conceptualization; formal analysis; funding acquisition; investigation; methodology; writing – original draft. **Matthew Moore:** Data curation; formal analysis; methodology; software; supervision; writing – review and editing. **Jacqueline Hannam:** Conceptualization; formal analysis; methodology; supervision; writing – review and editing. **Garth Poole:** Conceptualization; methodology; project administration; supervision; writing – review and editing. **Adam Bartlett:** Conceptualization; investigation; methodology; project administration; supervision; writing – review and editing. **Alan Merry:** Conceptualization; formal analysis; investigation; methodology; project administration; supervision; writing – review and editing.

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