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Variation in length of stay after minimally invasive lung resection: a reflection of perioperative care routines?

Erik M. von Meyenfeldt [a,*,†], Fieke Hoeijmakers[b,c,†], Geertruid M.H. Marres [a], Eric R.E. van Thiel [d], Elske Marra [c], Perla J. Marang-van de Mheen [e,‡] and Hermien (W.) H. Schreurs[f,‡]

[a] Department of Thoracic Surgery, Lung Cancer Centre, Albert Schweitzer Hospital, Dordrecht, Netherlands
[b] Department of Surgery, Leiden University Medical Centre, Leiden, Netherlands
[c] Scientific Bureau, Dutch Institute for Clinical Auditing, Leiden, Netherlands
[d] Department of Thoracic Oncology, Lung Cancer Centre, Albert Schweitzer Hospital, Dordrecht, Netherlands
[e] Department of Biomedical Data Sciences, Medical Decision Making, Leiden University Medical Centre, Leiden, Netherlands
[f] Department of Thoracic Surgery, Northwest Clinics, Alkmaar, Netherlands

* Corresponding author. Department of Thoracic Surgery, Lung Cancer Centre, Albert Schweitzer Hospital, PO Box 444, 3300 AK Dordrecht, Netherlands. Tel: +31-78-6541111; fax: +31-78-6541736; e-mail: e.m.von.meyenfeldt@asz.nl (E.M. von Meyenfeldt).

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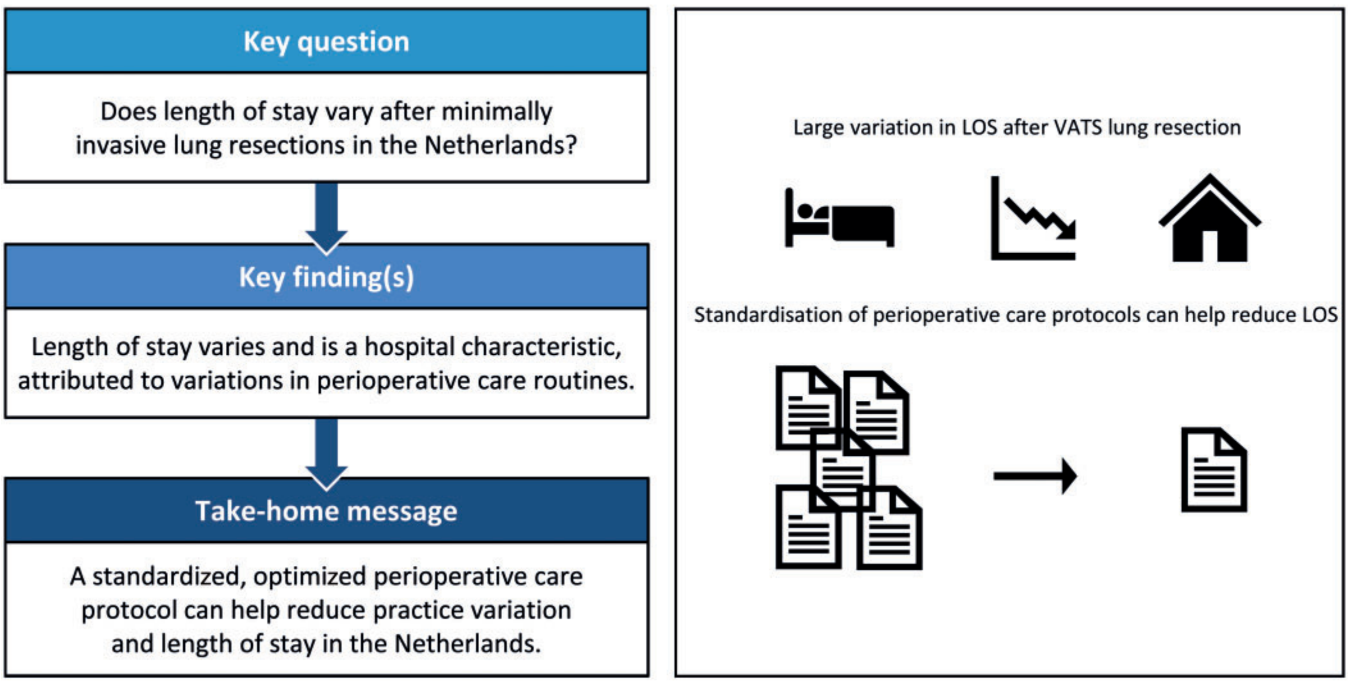

Abstract

OBJECTIVES: Good perioperative care is aimed at rapid recovery, without complications or readmissions. Length of stay (LOS) is influenced not only by perioperative care routines but also by patient factors, tumour factors, treatment characteristics and complications. The present study examines variation in LOS between hospitals after minimally invasive lung resections for both complicated and uncomplicated patients to assess whether LOS is a hospital characteristic influenced by local perioperative routines or other factors.

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†These authors contributed equally as first author.
‡These authors contributed equally as supervisors.

THORACIC

METHODS: Dutch Lung Cancer Audit (surgery) data were used. Median LOS was calculated on hospital level, stratified by the severity of complications. Lowest quartile (short) LOS per hospital, corrected for case-mix factors by multivariable logistic regression, was presented in funnel plots. We correlated short LOS in complicated versus uncomplicated patients to assess whether short LOS clustered in the same hospitals regardless of complications.

RESULTS: Data from 6055 patients in 42 hospitals were included. Median LOS in uncomplicated patients varied from 3 to 8 days between hospitals and increased most markedly for patients with major complications. Considerable between-hospital variation persisted after case-mix correction, but more in uncomplicated than complicated patients. Short LOS in uncomplicated and complicated patients were significantly correlated ($r = 0.53$, $P < 0.001$).

CONCLUSIONS: LOS after minimally invasive anatomical lung resections varied between hospitals particularly in uncomplicated patients. The significant correlation between short LOS in uncomplicated and complicated patients suggests that LOS is a hospital characteristic potentially influenced by local processes. Standardizing and optimizing perioperative care could help limit practice variation with improved LOS and complication rates.

Keywords: Lung resection • Length of stay • Perioperative care • Enhanced recovery after thoracic surgery

ABBREVIATIONS

ASA	American Society of Anaesthesiologists
CL	Control limits
DLCA-S	Dutch Lung Cancer Audit for Surgery
ECOG PS	Eastern Cooperation Oncology Group Performance Score
ERAS	Enhanced Recovery After Surgery
ESTS	European Society of Thoracic Surgeons
IQR	Interquartile range
LOS	Length of stay
MIS	Minimally invasive surgery
NNCR	Netherlands National Cancer Registry
NSCLC	Non-small-cell lung cancer
TNM	Tumour Node Metastasis
VATS	Video-assisted thoracic surgery

INTRODUCTION

Good perioperative care is aimed at rapid recovery after surgery, without complications or readmissions [1]. At present, there is no comprehensive guideline for perioperative care in lung cancer patients in the Netherlands.

Length of stay (LOS) has been used as a quality measure of perioperative care, but short LOS does not automatically equate good quality of care, as LOS is dependent on many factors [1, 2]. Perioperative care routine plays a role, as do patient and tumour factors—so called case-mix factors—as well as treatment characteristics and complications [2–4]. In order to be able to use LOS as an indicator for clinically important variation in perioperative care routine, all other factors should be corrected for.

A recent, previously published, study of data from the Netherlands National Cancer Registry (NNCR) showed a large variation in LOS between Dutch hospitals after case-mix correction, irrespective of hospital volume. It was considered that this variation was largely attributable to differences in perioperative care [5]. The NNCR analysis, however, had its limitations. As detailed information on comorbidity is not available in the NNCR, the extent of case-mix correction was limited. Lack of data on complications and readmission in the NNCR database limited the ability to assess the relationship between variation in LOS and these quality-of-care parameters. These limitations inspired the current study.

In the more elaborate Dutch Lung Cancer Audit for Surgery (DLCA-S) database, data on comorbidity, complications and readmissions are collected. This offers the opportunity to analyse variation in LOS in complicated and uncomplicated cases separately, in order to distinguish between LOS as a hospital characteristic versus variation in LOS as a result of complications. The effect of differences in perioperative care routines between hospitals on LOS will be most clear in uncomplicated patients.

As in many hospitals different perioperative care protocols are used for open and minimally invasive surgery (MIS), including these 2 surgical approaches in 1 analysis of perioperative care protocols did not seem appropriate. In order to obtain the purest comparison, we decided to focus on the most commonly used surgical approach in the Netherlands: MIS with rates increasing from 50% in 2012 to 63% in 2017 [6]. From the total number of MIS procedures, multiportal video-assisted thoracic surgery (VATS) was used in 92.8%, uniportal VATS (for which registration started in 2017) in 3.6% and robot-assisted thoracic surgery in 3.6%.

MATERIALS AND METHODS

Data source

Data were retrieved from the DLCA-S database, after mandatory approval of the Privacy Review Board of DLCA-S (30 August 2018; DLCAS201702), in accordance with the Dutch Personal Data Protection Act that was applicable in the period 2012–2017. Consent of patients has been waived. The DLCA-S is a mandatory, nationwide registry run by the Dutch Institute for Clinical Auditing (DICA) collecting data from all General Thoracic Surgery Units in the Netherlands since 2012 [6].

Patient selection

Patients were selected for this analysis if they underwent minimally invasive anatomical lung resection [i.e. pneumonectomy, (bi)lobectomy or segmentectomy] for suspected or proven non-small-cell lung cancer (NSCLC) between 1 January 2012 and 31 December 2017. In order to consider a patient eligible for this analysis, the following items had to be registered: gender, date of surgery, age at time of surgery, type of tumour and vital status 30 days after surgery and/or at time of discharge. Patients were excluded if they underwent acute surgery or if they died within

30 days after surgery, because this would confound the association with short LOS. Additionally, patients with a missing date of discharge or negative LOS were excluded because of evident registration errors, as well as patients from hospitals who discontinued performing lung surgery in the study period.

Definitions

Tumour stage was recorded according to the Tumour Node Metastasis (TNM) Classification of Malignant Tumours from the International Union Against Cancer (UICC). The 7th edition was used for patients from 2012 to 2016; the 8th edition was used for patients in 2017 [7, 8].

As not all complications will influence LOS equally, a distinction was made between minor and major complications. Minor complications were defined as any complication without surgical reintervention and major complications as any complication with surgical reintervention.

Methods

Statistical analysis. Overall median LOS was calculated for the whole population and for uncomplicated and complicated (minor and major complications) patients separately. Baseline patient characteristics for uncomplicated and complicated patients were described using descriptive statistics and compared using χ^2 test for categorical variables and Mann–Whitney *U*-test for non-normally distributed continues variables.

Median LOS was calculated for each hospital—both overall and by complication level (no complications vs minor vs major complications)—to show the effect of complications on LOS, relative to other hospitals.

Subsequently, LOS corrected for patient, tumour and treatment characteristics, that is, case-mix factors, was analysed in order to evaluate between-hospital variation in perioperative care routine. Because LOS is not normally distributed, LOS was dichotomized based on a cut-off at the lowest quartile of LOS for all included patients (uncomplicated and complicated together), which is ≤4 days.

Based on literature, the following factors were included to adjust for differences in case mix: age, gender, lung function (a composite measure of forced expiratory volume in 1 s percentage of normal and diffusing lung capacity for oxygen percentage of normal), Charlson Comorbidity Index, Eastern Cooperation Oncology Group Performance Score (ECOG PS), American Society of Anaesthesiologists (ASA) classification, induction therapy, extent of resection [(bi)lobectomy, pneumonectomy, segmentectomy], pathological T-stage, histological type and year of surgery [9–12]. Univariable logistic regression was performed separately for uncomplicated patients and for patients who experienced any (minor or major) complication, to calculate the probability of lowest quartile LOS (≤4 days) for every patient. Factors with a *P*-value <0.10 were then included in multivariable logistic regression models, after checking for multicollinearity. Using backwards elimination, only statistically significant variables were retained in the final case-mix models. Subsequently, the expected (E) number of patients with lowest quartile LOS was calculated for each hospital based on the patient-level probabilities. The observed (O) number of patients with lowest quartile LOS was then divided by the expected number of patients with lowest quartile LOS for each hospital (O/E-ratio). Differences in O/E ratio between hospitals were shown in funnel plots with a 95%- and 99.8%-control limits (CL). To correct for multiple testing, a hospital was considered an outlier hospital if outside the 99.8%-CL. A ratio >1 means more patients with lowest quartile LOS than expected based on the hospitals case mix and a ratio <1 means less patients than expected with lowest quartile LOS.

The effect of routine perioperative care is likely to be most clearly shown in the group of uncomplicated patients. However, care in complicated cases in each hospital will, at least partly, be comparable to care in uncomplicated cases. In order to evaluate whether LOS—as a consequence of perioperative care—is a hospital characteristic, we assessed if the outlier hospitals in uncomplicated patients were also outlier hospitals in complicated patients, by marking the outliers in the funnel plot of uncomplicated patients in the funnel plot of complicated patients.

Ultimately, in order to estimate the magnitude of this hospital-level association, we correlated the hospital-level O/E ratio for short LOS in complicated patients with the O/E ratio for short LOS in uncomplicated patients using Pearson correlation coefficients. The lowest quartile LOS was used to define short LOS, calculated separately for uncomplicated (≤4 days) and complicated (≤7 days) patients to reflect a relatively short LOS, given occurrence of complications. Because of a large percentage of missing data (72.3%) regarding readmissions, the intended analysis of correlation between short LOS and readmission could not be performed. LOS did not differ between the groups no readmission [median 6 days, interquartile range (IQR) 4–9], readmission (median 6 days, IQR 4–9) and missing data about readmission (median 6 days, IQR 4–8).

P-values of <0.05 were considered statistically significant. All statistical analyses were performed using SPSS (IBM SPSS Statistics for Macintosh, Version 25.0).

RESULTS

Based on the inclusion and exclusion criteria, 6055 of the 6196 consecutive patients (98%) from 42 hospitals were included. They all underwent oncological resections for proven or suspected lung cancer. For all these patients, as per guidelines, nodal dissection is required. We found in our data only 1.1% of patient without dissection of any lymph node [the other 98.9% had dissection of at least 1 node (82.5%) or missing data (16.4%)], and reasons for not performing a nodal dissection are not reported. Patients were excluded because of acute surgery (*n* = 4), death within 30 days after surgery (*n* = 71), a missing day of discharge (*n* = 10), a negative LOS (*n* = 10) or because their hospital was excluded from the analyses (*n* = 49).

Patients with complications (*n* = 1813) were statistically significantly different from patients without complications (*n* = 4242) with respect to most baseline characteristics (Table 1). Overall median LOS was 6 days (IQR 4–8). In patients without complications, median LOS was 5 days (IQR 4–7); in patients with complications, median LOS was 9 days (IQR 7–14) (Table 1).

Variation in length of stay on hospital level, uncorrected

The median LOS of uncomplicated patients varied from 3 to 8 days (Fig. 1A). Differences in LOS by complication level were shown for each hospital in Fig. 1B, with each line representing a

Table 1: Baseline patient, treatment and tumour characteristics

Patient characteristics	Without complications [*n* = 4242 (70%)]	With complications [*n* = 1813 (30%)]	*P*-value[a]
Age (years), mean (SD)	65.4 (9.3)	67.2 (8.8)	
Age by category, *n* (%)			<0.000
<60	1050 (24.8)	338 (18.7)	
60–69	1663 (39.3)	690 (38.1)	
70–79	1323 (31.2)	678 (37.4)	
80+	200 (4.7)	106 (5.8)	
Gender, *n* (%)			<0.000
Male	2045 (48.2)	1013 (55.9)	
Female	2197 (51.8)	800 (44.1)	
Charlson comorbidity index, *n* (%)			<0.000
0	1434 (33.8)	498 (27.5)	
1	1182 (27.9)	504 (27.8)	
2+	1626 (38.3)	811 (44.7)	
ECOG performance score, *n* (%)			0.043
0–1	3436 (81.0)	1454 (80.2)	
2+	109 (2.6)	68 (3.8)	
Unknown/missing	697 (16.4)	291 (16.1)	
ASA score, *n* (%)			<0.000
1–2	3089 (72.8)	1164 (64.2)	
3+	993 (23.4)	581 (32.0)	
Unknown/missing	160 (3.8)	68 (3.8)	
Cardiac comorbidity, *n* (%)			0.008
No	3191 (75.2)	1305 (72.0)	
Yes	1051 (24.8)	508 (28.0)	
Pulmonary comorbidity, *n* (%)			<0.000
No	2870 (67.6)	1048 (57.8)	
Yes	1372 (32.4)	765 (42.2)	
Lung function, *n* (%)			<0.000
FEV1[b] and DLCO[c] ≥80%	1633 (38.5)	502 (27.7)	
FEV1[b] or DLCO[c] <80%	2383 (56.2)	1210 (66.7)	
Both unknown/missing	226 (5.3)	101 (5.6)	
Induction therapy, *n* (%)			0.68
No/unknown	4140 (97.6)	1763 (97.2)	
Chemoradiotherapy	46 (1.1)	21 (1.2)	
Different	56 (1.3)	29 (1.6)	
Type of surgery, *n* (%)	62 (1.5)	24 (1.3)	
Pneumonectomy			<0.000
Bilobectomy	125 (2.9)	73 (4.0)	
Lobectomy	3912 (92.2)	1683 (92.8)	
Segmentectomy	143 (3.4)	33 (1.8)	
pT-stage,[d] *n* (%)			0.24
pT1a–c (and T0, Tis)	1983 (46.7)	816 (45.0)	
pT2a–b	1544 (36.4)	655 (36.1)	
pT3	371 (8.7)	188 (10.4)	
pT4	90 (2.1)	46 (2.5)	
Unknown/Tx	254 (6.0)	108 (6.0)	
Postoperative histopathology, *n* (%)			<0.002
Benign	178 (4.2)	69 (3.8)	
Adenocarcinoma	2525 (59.5)	1045 (57.6)	
Squamous cell	927 (21.9)	487 (26.9)	
Different NSCLC	433 (10.2)	137 (7.6)	
SCLC	51 (1.2)	20 (1.1)	
Other/unknown	128 (3.0)	55 (3.0)	
LOS (days), median (IQR)	5 (4–7)	9 (7–14)	<0.000[e]
Short LOS (lower quartile)			

[a] χ^2 test.

[b] FEV1, percentage of expected.

[c] DLCO, percentage of expected.

[d] According to TNM 7 from 2012 to 2016 and TNM8 in 2017.

[e] Mann–Whitney *U*-test.

ASA: American Society of Anaesthesiologists; DLCO: diffusing lung capacity for oxygen; ECOG: Eastern Cooperative Oncology Group; FEV1: forced expiratory volume in 1 s; IQR: interquartile range; LOS: length of stay; NSCLC: non-small-cell lung cancer; pT: pathological T; SCLC: small-cell lung cancer; SD: standard deviation; TNM: tumour node metastasis.

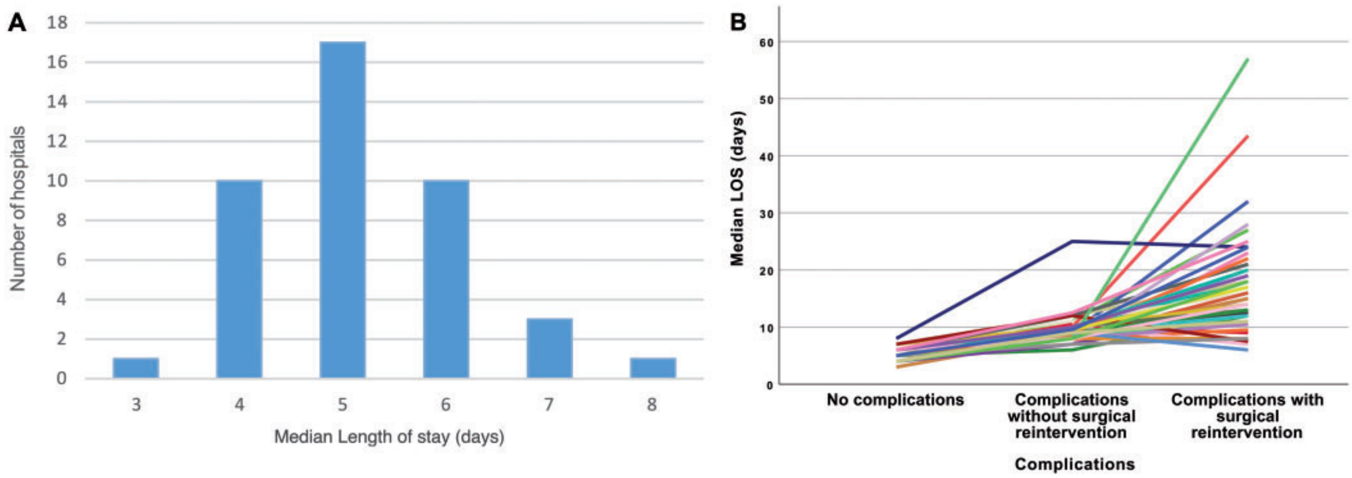

Figure 1: (**A**) Distribution of median LOS in days in uncomplicated patients. (**B**) Variation of median LOS in each hospital by complication level. LOS: length of stay.

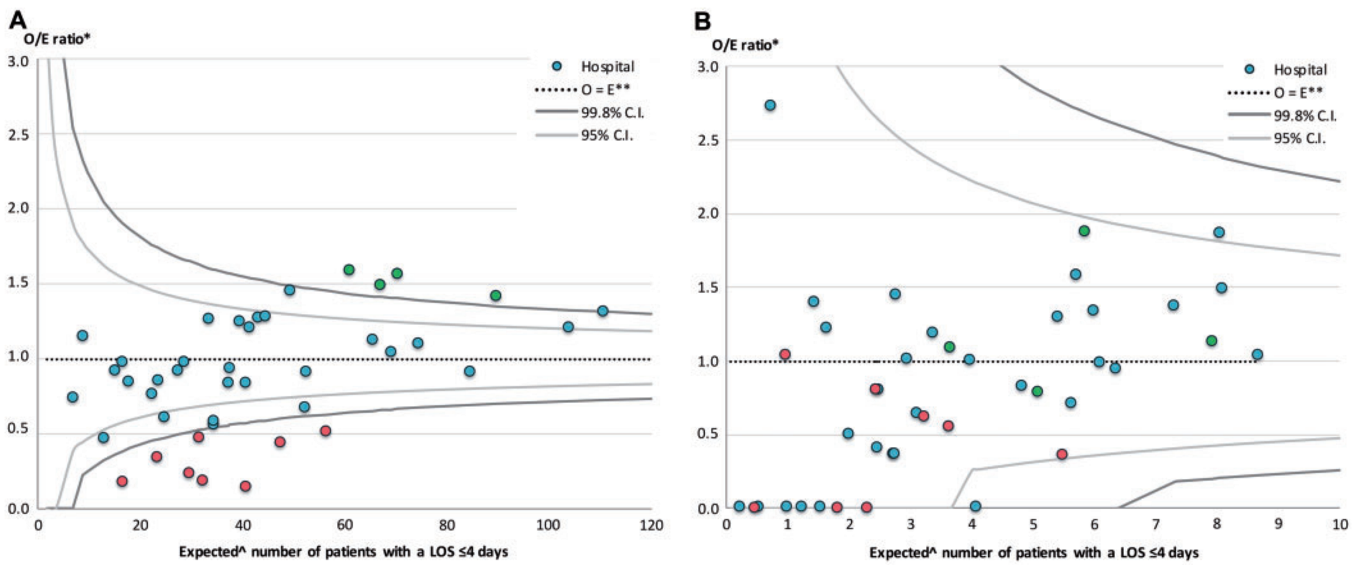

Figure 2: (**A**) Funnel plot of between-hospital variation in LOS in uncomplicated patients. The hospitals in green and pink had, respectively, statistically significantly more and less patients with lowest quartile LOS than expected based on their case mix. (**B**) Funnel plot of between-hospital variation in LOS in complicated patients. The hospitals marked green and pink in (**A**) are also marked green and pink in this funnel plot for complicated patients. CI: confidence interval; LOS: length of stay.

hospital. For each hospital, median LOS is increased in patients with minor complications and even further in patients with major complications. However, clear hospital variation is shown regardless of minor/major complications. Most lines run parallel, suggesting that hospitals with shorter median LOS in uncomplicated patient also frequently achieve shorter median LOS in patients with minor complications as well as patients with major complications.

In other words, LOS seems to be a hospital characteristic, as hospitals with shorter LOS in uncomplicated cases also have shorter LOS in complicated cases.

Variation in length of stay on hospital level, corrected

The funnel plots in Fig. 2A and B show the observed versus expected ratio of lowest quartile LOS for uncomplicated and complicated patients respectively. For uncomplicated patients, the following variables were predictors for lowest quartile LOS and included in the final case-mix model: age, gender, lung function, Charlson Comorbidity index, ECOG PS, ASA-classification, induction therapy, extent of resection, pathological T-stage, histological type and year of surgery. For complicated patients, the included predictors were: age, lung function, ASA-classification, extent of resection, histological type and year of surgery. There was no multicollinearity, all variance inflation factors below 2.0. Considerable between-hospital variation was observed, but seemingly more in uncomplicated than complicated patients. In the funnel plot of uncomplicated patients (Fig. 2A), more outlier hospitals ($n = 12$) were observed compared to the funnel plot of complicated patients ($n = 0$ outlier hospitals, Fig. 2B). In uncomplicated patients, 4 hospitals managed to discharge statistically significantly more patients in ≤4 days than expected based on their case mix (up to >50%) (represented in green in Fig. 2A), while 8 hospitals discharged statistically significantly less patients than expected in that time frame (up to

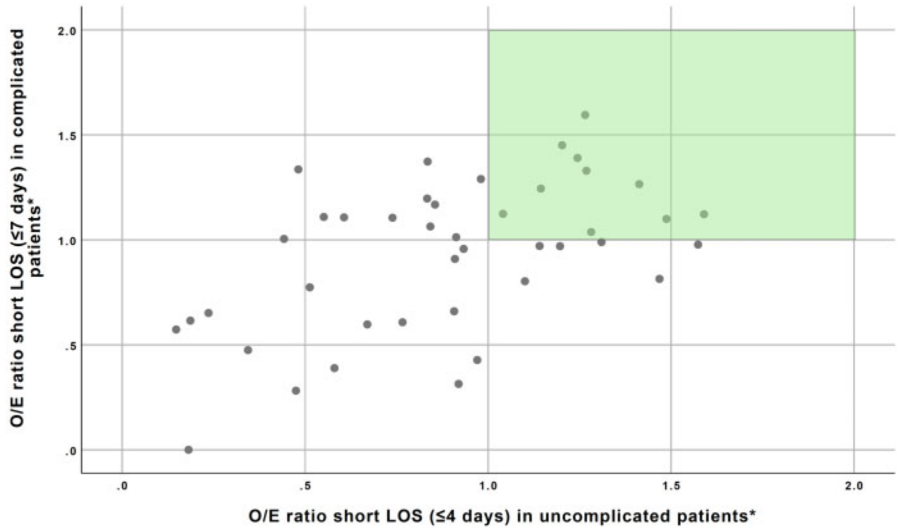

Figure 3: Hospital-level correlation between short LOS in uncomplicated and in complicated patients. LOS: length of stay.

>50%) (represented in pink in Fig. 2A). Although hospitals with shorter median LOS in uncomplicated patient also frequently achieve shorter median LOS in complicated patients, no hospitals were outliers beyond CL in both uncomplicated and complicated patients. Figure 2B shows that both positive and negative outlier hospitals for uncomplicated patients all were within the CL with respect to complicated patients.

Defining short LOS conditional on having complications or not, Fig. 3 shows that short LOS in uncomplicated patients was statistically significantly correlated with short LOS in complicated patients on hospital level ($r = 0.525$, $P < 0.001$). The hospitals in the green quarter of Fig. 3 ($n = 10$) are able to achieve relatively short LOS in both uncomplicated and complicated patients.

DISCUSSION

The present study showed considerable variation in LOS after minimally invasive anatomical lung resections for NSCLC between Dutch hospitals, persisting after adjustment for case mix. The variation between hospitals achieving short LOS was most pronounced in the uncomplicated patient group but was also seen in patients with complications. Furthermore, a statistically significant correlation between short LOS in uncomplicated and complicated patients was found on hospital level. This means that hospitals with relatively short LOS in uncomplicated patients also have relatively short LOS in complicated patients. These outcomes suggest that LOS may be a hospital characteristic potentially influenced by local processes.

As was stated in the introduction, short LOS is not a goal in itself, but a consequence of rapid postoperative recovery. Good perioperative care and swift and adequate treatment of complications as well as the ability to discharge patients to their homes or to a care facility when discharge criteria are met should lead to short LOS.

As demonstrated in the case mix-corrected funnel plots, some hospitals are able to achieve short LOS for statistically significantly more patients than expected based on their case mix. Part of these hospitals also had a relatively short LOS in complicated patients, as shown by the moderate, but statistically significant, correlation in Fig. 3. This moderate correlation suggests that even if these hospitals were not able to prevent complications from occurring, the LOS was still relatively short, possibly as a result of perioperative care routine in the hospital or other local processes. On the other hand, hospitals may differ in the severity and number of complications, which is likely to influence LOS far more than perioperative care routines, resulting in a moderate rather than strong correlation. This implicates that perioperative care routine influences LOS, reflected by the proportion of patients not achieving short LOS despite correcting for other known factors known to influence LOS such as case-mix factors or complications. Good perioperative care and swift and adequate treatment of complications as well as the ability to discharge patients to their homes or to a care facility when discharge criteria are met could lead to a higher proportion of short LOS in these hospitals. No statements can be made on what processes lead to short LOS, combined with limited complications, due to lack of data regarding perioperative care elements such as pain management, chest drain removal criteria, early mobilization or other elements associated with enhanced recovery in the DLCA-S database. The rather long median LOS of 6 days after MIS in uncomplicated patients and the variation in LOS between hospitals, however, suggest room for improvement of perioperative care routine in the Netherlands.

Publications on the effect of Enhanced Recovery After Surgery (ERAS) programmes in other surgical fields, but also in lung resections, focus on the positive potential of standardization and optimization of perioperative care protocols [1, 4, 13–15]. Reduction of LOS, complication rates and cost are all reported outcomes associated with adoption of these programmes. Recently, the 'Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS)' were published, offering an opportunity to address the practice variation described in the current study [16]. Further evaluation of differences in approach towards perioperative care between Dutch hospitals and comparison to the ERAS®/ESTS guideline recommendations is currently being performed.

The current findings support earlier conclusions from analyses of the NNCR database that variation in LOS is strongly associated with hospital and thus may be related to variations in perioperative care routines between those hospitals [5]. The current results are more robust by an improved case-mix correction using comorbidity data and by including the influence of complications, showing that some hospitals were able to achieve relatively short LOS for both uncomplicated and complicated patients.

Limitations

As the data were self-reported by physicians, particularly minor complications may be underreported, which seems to be supported by the relatively small differences found between uncomplicated patients and those with minor complications in most hospitals. However, previous validation of the DLCA-S database showed that only 3.3% of complications were missing, so it is not likely that it affected our results [17].

Unfortunately, the question regarding readmissions was not mandatory in the DLCA-S database and a large percentage of data (73.5%) regarding readmissions were missing. Therefore, it was not possible to assess the relationship between LOS and readmissions on hospital level and to correlate readmissions to short LOS. This omission probably did not considerably influence our conclusions, as previously published data from several groups suggest that improvement in perioperative care with decreased LOS does not lead to increased readmissions [2, 18, 19]. This assumption is strengthened by the fact that median LOS did not differ between patients with and without readmission or missing data.

CONCLUSION

In conclusion, between-hospital variation in postoperative LOS after minimally invasive anatomical lung resections—especially in uncomplicated patients—is present in the Netherlands. This most likely reflects the local perioperative care routines, given the fact that some hospitals achieved relatively short LOS for both complicated and uncomplicated patients. Standardization and optimization of the perioperative care routine in the Netherlands, for instance using recommendations of the recently published ERAS/ESTS guidelines, could help more hospitals to achieve the same standards of a short LOS with limited complication rates in Dutch hospitals.

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Author contributions

Erik M. von Meyenfeldt: Conceptualization; Formal analysis; Investigation; Methodology; Visualization; Writing—Original draft. **Fieke Hoeijmakers:** Data curation; Formal analysis; Methodology; Writing—Original draft. **Geertruid M.H. Marres:** Conceptualization; Supervision; Writing—Review & Editing. **Eric R.E. van Thiel:** Writing—Review & Editing. **Elske Marra:** Methodology. **Perla J. Marang-van de Mheen:** Methodology; Supervision; Visualization; Writing—Review & Editing. **Hermien (W.) H. Schreurs:** Conceptualization; Supervision; Writing—Review & Editing.

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