



Influence of Daily Variations in Individual Surgeon's Operative Time on Patient Outcomes

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Abstract

Background Evidence is lacking regarding the potential association between daily variation in individual surgeon's operative time, procedure after procedure, and risk of patient complication. We assumed that surgeon deviation from the expected procedure duration may be harmful for patient.

Method All patients who underwent a thyroidectomy undertaken in five hospitals during a 1-year period were included prospectively. For each thyroidectomy, we estimated the expected operative time from a multilevel linear regression considering the attending surgeon who performed the operation, the patient preoperative risk, and the procedure complexity. Three groups of thyroidectomies were identified according to whether the observed duration is: slower than expected, as expected, or faster than expected. Rates of permanent recurrent laryngeal nerve palsy and hypoparathyroidism at 6 months were then compared between these groups.

Results A total of 3102 patients who underwent a thyroidectomy undertaken by 22 surgeons were considered. Risk of laryngeal nerve palsy was higher in the “slow” group than in the “normal” group (OR = 4.63, 95% confidence interval 2.21–9.70), as was that of hypoparathyroidism (OR = 2.43, 95% confidence interval 1.21–4.88). There was no significant difference between “fast” and “normal” groups for either complication. Deviation from expected procedure duration was more frequent at the end than at the beginning of the daily operation schedule (29.4% vs. 18.3%, respectively, $P < .001$).

Conclusion Patients had a greater risk of complication when the surgeon performed thyroidectomy slower than expected. Surgeons avoiding excessive deviations from their expected procedures durations reflect safer practice.

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Introduction

Avoiding lengthened surgical duration is the surgeon's daily quest to preserve operating room scheduling [1]. Operative time is influenced by patient preoperative risk, procedure complexity, and intraoperative difficulties or team disorganization [2–5]. Not all of these factors may be anticipated, yet an expert surgeon is expected to perform a given procedure with highly reproducible duration, irrespective of the patient and working context.

The vast majority of studies investigating the relationship between operative time and surgical complications have focused on patient features [6–11]. Such studies do not take into consideration accurately the surgeon in charge of the surgical procedure, although it is known this is a major factor determining surgical duration and there are large variations between surgeons [12]. Furthermore, even highly skilled surgeons experience variations in their daily performance [13, 14], but evidence is lacking regarding the potential association between variation in operative time for an individual surgeon and patient safety. We assumed that surgeon's deviation from the expected procedure duration may be harmful for patients [15]. For a given surgeon, we aimed to determine whether patients exposed to unexpectedly long or short thyroidectomy duration could be at increased risk of complication.

Methods

Study design and population

In order to evaluate the association between variation in individual surgeon operative time and patient outcomes, we focused on thyroid surgery which represents a model particularly adapted for this purpose.

We conducted a prospective study between 1 April 2008 and 31 December 2009 in five public high-volume referral centres in France. All endocrine surgeons who performed at least 30 thyroid procedures in these centres during a 1-year period participated in the study. All patients who underwent thyroidectomy performed by these surgeons were eligible for inclusion.

We defined three groups of procedures according to operative time deviations, as follows: the operative time of each procedure was classified as either slower than expected, as expected, or faster than expected considering the attending surgeon who performed the operation, the patient preoperative risk, and the procedure complexity (refer to statistical analysis section for details). The rates of permanent laryngeal nerve palsy and hypoparathyroidism between these three groups were then compared.

The study was approved by the regional ethics committee (*Comité de Protection des Personnes Sud-Est III*). Informed consent was obtained from participating surgeons; requirement for patient consent was waived by the ethics committee. Before surgery, patients received written information about the use of their personal data and given the opportunity to refuse the use of their data for research purposes.

Data collection and outcomes

After each thyroidectomy, a patient report form with closed questions was completed by the attending surgeon, including items about surgical indication, procedure complexity, as well as items relating to his/her perception of the procedure complexity: difficult parathyroid or recurrent nerve identification, large or substernal goitre, hypervascularization, intense fibrosis or thyroiditis, and invasive cancer, and also the surgeon's identity and the presence of a more experienced supervisory surgeon during the intervention. The study cohort did not include endoscopic thyroid cases or the use of ultrasonic bipolar device. Research assistants collected data from patient medical records, including demographic characteristics, thyroid specimen weights, post-operative supplementation with calcium or vitamin D (or both), calcium assay values, and assessment of vocal cord mobility. Operative time was measured in minutes (min) and defined as the total duration from skin incision to closure of the wound.

We considered two major complications of thyroid surgery that reflect how the operator masters thyroid surgical technique [16]: permanent laryngeal nerve palsy and permanent hypoparathyroidism. To diagnose permanent complications, an assessment was planned at least six months after the thyroidectomy. The permanent laryngeal nerve palsy rate was measured in patients who underwent unilateral or bilateral thyroid procedures. Post-operative vocal cord mobility was assessed by laryngoscopy [17]. Exclusion criteria for permanent laryngeal nerve palsy analysis included pre-existing nerve palsy before the intervention, previous thyroid surgery with unknown pre-existing nerve palsy status, voluntary resection of nerves during intervention due to invasive carcinoma, and patient death during follow-up. Owing to organizational constraints in one centre, systematic laryngoscopy was not feasible after each thyroid procedure. This centre was not included in the permanent laryngeal nerve palsy analysis. The permanent hypoparathyroidism rate was measured in patients who underwent a bilateral thyroidectomy. We defined post-operative hypoparathyroidism as a serum calcium concentration below 2 mmol/L or a requirement for vitamin D or/and calcium supplementation to maintain healthy calcium concentrations after thyroidectomy [18].

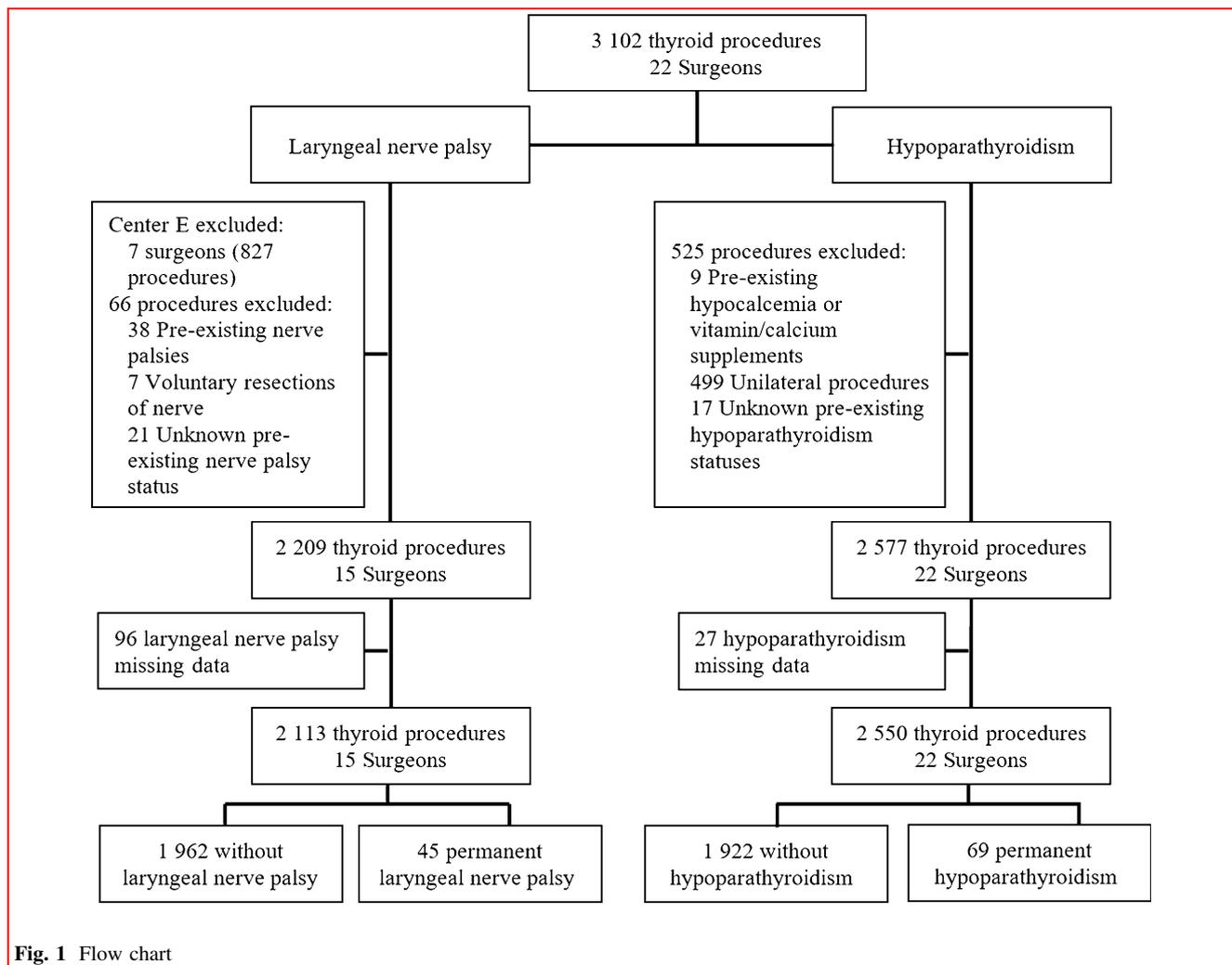
Exclusion criteria for permanent hypoparathyroidism included unilateral lobectomy, pre-existing hypocalcaemia or substitutive therapy with calcium and/or vitamin D before intervention, previous thyroid surgery with unknown pre-existing parathyroid status, and patient death during follow-up.

Statistical analysis

To calculate each expected operative time, we used a multilevel linear regression. This model dealt with observations that were not independent, in this case the clustering of procedures performed by the same surgeon. Thus, our statistical model considered the surgeon in charge of operation (i.e. clustering effect of procedures within surgeons) as well as adjustments on several variables related to patient preoperative characteristics (age, sex, BMI, thyroid disease), procedure complexity (weight of thyroid specimen, large goitre, substernal goitre, haemorrhagic goitre, presence of fibrosis or thyroiditis, invasive cancer,

lymph node dissection, difficulties in locating parathyroid gland or recurrent laryngeal nerve, bilateral procedure), and mentoring (supervision by more experienced surgeon) in accordance with methodology developed in our previous research [5]. Subsequently, procedures were divided into three groups based on whether their observed duration was slower than the expected operative time (“slow”), as the expected operative time (“normal”), or faster than the expected operative time (“fast”). The “fast” group corresponded to procedures for which the surgeon operated at least 50% faster than expected for himself/herself, and “slow” group corresponded to procedures for which the surgeon operated at least 50% slower than expected.

Permanent complication rates were compared between the three groups of procedures using the Chi-square test. Logistic regressions were used to estimate the odds ratio and their 95% confidence interval of permanent complications between the “slow” or “fast” group and the “normal” group. The distribution of thyroidectomies according to the order in the surgeon’s daily thyroid



surgical schedule was described and compared between the three defined groups using a Cochran–Armitage test for trend. All statistical analyses were performed using SAS software version 9.04 (SAS Institute Inc., Cary, NC, USA). All tests were two tailed, and $P < .05$ was considered statistically significant. Categorical variables are presented using absolute and relative frequencies. Continuous variables are presented using means and standard deviation (SD).

Results

We identified 2113 thyroid procedures for permanent laryngeal nerve palsy analysis (Fig. 1). Surgeons operated faster than expected in 12.1% (256/2113) of thyroidectomies and slower than expected in 6.2% (132/2113) of

thyroidectomies (Table 1). The mean operative time was 57 min (SD = 30) for the “fast” group, 88 min (SD = 44) for the “normal” group, and 153 min (SD = 64) for the “slow” group. Rate of permanent laryngeal nerve palsy was significantly higher in the “slow” group (7.58%, 10/132) than in the “normal” (1.74%, 30/1725) and “fast” (1.95%, 5/256) groups ($P < .001$, Table 1). Risk of permanent laryngeal nerve palsy was significantly higher in the “slow” group than in the “normal” group (OR = 4.63, 95% confidence interval 2.21–9.70, $P < .001$); there was no significant difference between “fast” and “normal” groups (OR = 1.13, 95% confidence interval 0.43–2.93, $P = .81$, Fig. 2).

We identified 2550 thyroidectomies for permanent hypoparathyroidism analysis (Fig. 1). Surgeons operated faster than expected in 12.5% (318/2550) of thyroidectomies and slower than expected in 6.7% (172/2550) of

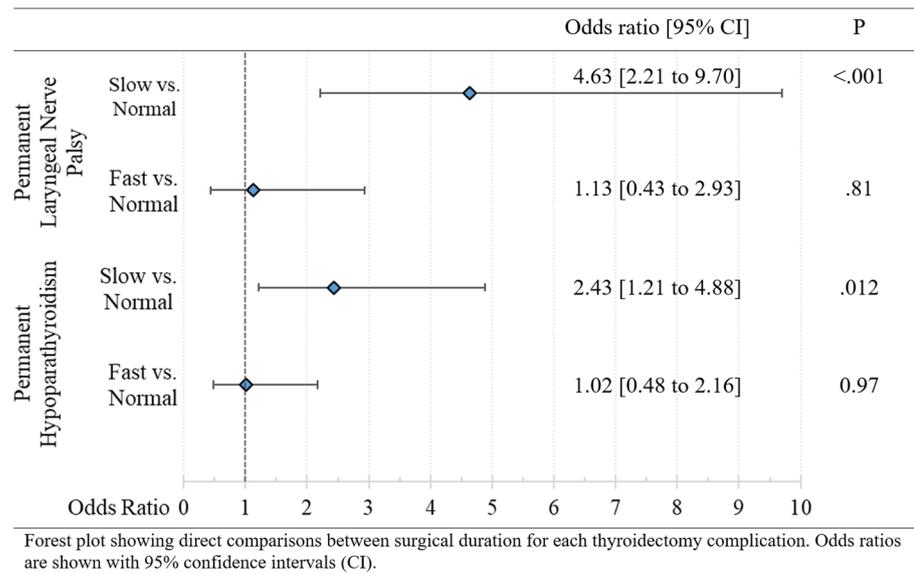
Table 1 Population characteristics for laryngeal nerve palsy analysis according to deviations from the expected operative time

Baseline characteristics	Faster ($n = 256$)	Normal ($n = 1725$)	Slower ($n = 132$)
Age (years)*	50 (16)	51 (15)	51 (15)
Sex (F/M)	203:53	1 351:374	91:41
BMI (kg/m^2)*	26 (6)	26 (5)	26 (5)
<i>Thyroid disease</i>			
Non-toxic solitary nodule	28 (10.9)	246 (14.3)	27 (20.5)
Non-toxic multinodular goitre	138 (53.9)	962 (55.8)	61 (46.2)
Hyperthyroidism	21 (8.2)	201 (11.7)	10 (7.6)
Graves' disease	27 (10.6)	180 (10.4)	7 (5.3)
Malignant neoplasm	42 (16.4)	136 (7.9)	27 (20.5)
Weight of thyroid specimen (grams)*	50 (70)	45 (43)	43 (45)
Large goitre	37 (14.5)	270 (15.7)	17 (12.9)
Substernal goitre	28 (10.9)	178 (10.3)	15 (11.4)
Haemorrhagic goitre	15 (5.9)	192 (11.1)	5 (3.8)
Fibrosis	33 (12.9)	152 (8.8)	11 (8.3)
Thyroiditis	12 (4.7)	92 (5.3)	5 (3.8)
Invasive cancer	5 (2.0)	7 (0.4)	3 (2.3)
Bilateral procedure	207 (80.9)	1 422 (82.4)	98 (74.2)
Lymph node dissection	33 (12.9)	109 (6.3)	21 (15.9)
Difficulties locating parathyroid gland	58 (22.7)	365 (21.2)	23 (17.4)
Difficulties locating recurrent laryngeal nerve	62 (24.2)	426 (24.7)	25 (18.9)
Supervision by more experienced surgeon	20 (7.8)	128 (7.4)	23 (17.4)
<i>Surgeon's experience</i>			
≤ 4 years	75 (29.3)	676 (39.2)	34 (25.8)
5–19 years	67 (26.2)	355 (20.6)	27 (20.5)
≥ 20 years	114 (44.5)	694 (40.2)	71 (53.8)
Surgical duration (min)*	57 (30)	88 (44)	153 (64)
Permanent laryngeal nerve palsy	5 (2.0)	30 (1.7)	10 (7.6)

Values in parentheses are percentages unless indicated otherwise

*Values are mean (SD)

Fig. 2 Risk of permanent complications according to deviations from the expected operative time. Forest plot showing direct comparisons between surgical durations for each thyroidectomy complication. Odds ratios are shown with 95% confidence intervals (CI)



thyroidectomies (Table 2). The mean operative time was 62 min (SD = 31) for the “fast” group, 97 min (SD = 44) for the “normal” group, and 164 min (SD = 64) for the “slow” group. Rate of permanent hypoparathyroidism was higher in the “slow” group (5.81%, 10/172) than in the “normal” (2.48%, 51/2060) and “fast” (2.52%, 8/318) groups ($P = .03$, Table 2). Risk of permanent hypoparathyroidism was significantly higher in the “slow” group than in the “normal” group (OR = 2.43, 95% confidence interval 1.21–4.88, $P = .01$); there was no significant difference between “fast” and “normal” groups (OR = 1.02, 95% confidence interval 0.48–2.16, $P = .97$, Fig. 2).

Surgeon deviations from expected procedures duration were more frequent at the end (29.4%, 37/126, of thyroidectomies were “slow” or “fast”) than at the beginning (18.3%, 313/1706) of the daily surgical schedule ($P < .001$, Fig. 3).

Discussion

This multicentre study investigated whether daily variations in individual surgeon operative times affected patient safety. Thyroidectomies with unexpectedly long or short duration were identified by considering the usual speed of every surgeon as well as patient preoperative and intraoperative factors. Patients experienced a higher risk of both permanent laryngeal nerve palsy and hypoparathyroidism when the surgeon deviated from the expected operative time. In particular, the complication rate was higher in case of lengthened thyroidectomy compared to normal operation duration. Extended procedures were more frequent at

the end of operating room scheduling, as surgeons tended to operate slower after performing more than three thyroidectomies the same day.

The results corroborate the assumption that surgeons performing a procedure slower than expected may reflect a lack of control in surgical technique with poor patient outcomes. Patients undergoing procedures with prolonged operative time have previously been reported to have more frequently complications in a wide range of surgical specialties [6–12, 19–23]. However, these studies considered patient and procedure characteristics as the main predictors of surgical duration without considering operative time variability between surgeons, although it is known that thyroidectomy duration is predominantly influenced by the characteristics of individual surgeon and centre organization and not solely those of patient or procedure [5]. Herein, we analysed operative time variations at the individual surgeon level according to his/her usual speed and independently from risks inherent to patient and procedure complexity. We thereby focused on “intra-surgeon” instead of “inter-surgeons” variability related to surgical durations, revealing that even a very fast surgeon can operate with less dexterity sometimes and expose his/her patients to more complications. Conversely, the results do not support an increased risk when a patient is operated more rapidly than expected [24, 25].

The strengths of the study include the a priori design, the prospective patient recruitment and data collection, and the objective measurement of performance that was based on permanent complications that were systematically assessed and collected. In addition, many potential confounders related to the patient case mix and other surgeon factors were controlled, allowing us to use accurate operative time

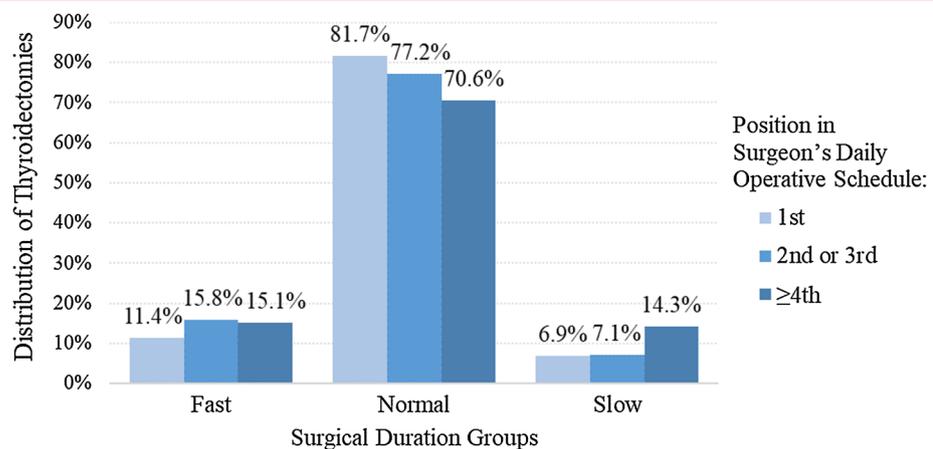
Table 2 Population characteristics for hypoparathyroidism analysis according to deviations from the expected operative time

Baseline characteristics	Faster (<i>n</i> = 318)	Normal (<i>n</i> = 2060)	Slower (<i>n</i> = 172)
Age (years)*	51 (14)	52 (15)	51 (15)
Sex (F/M)	243:75	1637:423	133:39
BMI (kg/m ²)*	26 (5)	26 (5)	26 (6)
<i>Thyroid disease</i>			
Non-toxic solitary nodule	7 (2.2)	86 (4.2)	13 (7.6)
Non-toxic multinodular goitre	188 (59.1)	1278 (62.0)	101 (58.7)
Hyperthyroidism	25 (7.9)	226 (11.0)	10 (5.8)
Graves' disease	33 (10.4)	248 (12.0)	11 (6.4)
Malignant neoplasm	65 (20.4)	222 (10.8)	37 (21.5)
Weight of thyroid specimen (grams)*	52 (69)	47 (43)	48 (51)
Large goitre	55 (17.3)	391 (19.0)	30 (17.4)
Substernal goitre	36 (11.3)	216 (10.5)	17 (9.9)
Haemorrhagic goitre	24 (7.6)	264 (12.8)	7 (4.1)
Fibrosis	37 (11.6)	179 (8.7)	16 (9.3)
Thyroiditis	14 (4.4)	126 (6.1)	7 (4.1)
Invasive cancer	8 (2.5)	16 (0.8)	4 (2.3)
Bilateral procedure	295 (92.8)	1947 (94.5)	154 (89.5)
Lymph node dissection	56 (17.6)	202 (9.8)	33 (19.2)
Difficulties locating parathyroid gland	57 (17.9)	430 (20.9)	30 (17.4)
Difficulties locating recurrent laryngeal nerve	78 (24.5)	538 (26.1)	40 (23.3)
Supervision by more experienced surgeon	36 (11.3)	141 (6.8)	21 (12.2)
<i>Surgeon's experience</i>			
≤ 4 years	100 (31.4)	928 (45.1)	46 (26.7)
5–19 years	60 (18.9)	357 (17.3)	29 (16.9)
≥ 20 years	158 (49.7)	775 (37.6)	97 (56.4)
Surgical duration (min)*	62 (31)	97 (44)	164 (64)
Permanent hypoparathyroidism	8 (2.5)	51 (2.5)	10 (5.8)

Values in parentheses are percentages unless indicated otherwise

*Values are mean (SD)

Fig. 3 Distribution of thyroidectomies according to deviations from the expected operative time and position in surgeon's daily operative schedule. Cochran–Armitage test for trend: $Z = -3.85$, $P < .001$



predictions and valid metrics for assessing the performance of individual surgeon, and thus avoiding coding bias resulting from the secondary use of administrative databases [14, 26–29]. Advantage of conducting the present study in thyroid surgery also related to the standardized nature of this procedure, with rapid access to the anatomical site and relatively weak influence of intraoperative events compared to most other invasive procedures [30]. Permanent complications were detected post-operatively and surgeons did not have the opportunity to formally detect and correct these during the course of the operation. Hence, operative time was not affected by their occurrence while it can be extended in other surgeries following major bleeding or other intraoperative event.

However, this observational study had several limitations and causal relationships are difficult to extrapolate. The generalization of the results to other surgical fields is uncertain because of the limited sample size of endocrine surgeons who practiced only in academic referral centres. It also cannot be excluded that other unknown or unmeasured factors might have explained at least part of the variation seen in operative time. Some residual variation in surgical duration was not explained by our prediction model [5], suggesting that aspects related to operating room organization, team familiarity, fatigue or unknown factors relative to surgical complexity were not considered and may have led to bias estimates of the expected operative times [31]. Furthermore, thyroid complications, such as laryngeal nerve palsy and hypoparathyroidism, reflect how the operator masters surgical technique [16] and permanent ones are diagnosed post-operatively, precluding correction by surgeon [17, 18]. However, we cannot exclude that intraoperative findings may have led to bias estimates of expected operative time as the surgeon might decide to repair an injured nerve or do a parathyroid implant.

The study findings evidence with large effect sizes that patient is at higher risk of complication when surgeons perform thyroidectomy slower than expected. Slower surgeon dexterity would determine poor patient outcomes independently from his/her usual operative time, the patient preoperative risk, or performed surgical procedure. Namely, when an expert surgeon excels in daily practice with an accurate control of surgical procedures duration, he/she will achieve the best performance with favourable patient outcomes. Such insight drives several implications to identify and then control human and organizational factors influencing surgeon's dexterity. The physical and mental state of individual surgeon at the time of procedure may be key to hold operative time under control. Greater attention to himself/herself must be taken by surgeon when turning out to be slower than usual. Furthermore, operating room

environment and team familiarity can influence procedure duration [32–34]. Auditory and mental distractions combined with surgeon's exhaustion are probably increasing over the day, while we observed that control of operative times deteriorates as the surgical schedule progress. It may represent a surgeon's greater susceptibility to factors that may slow him/her down in his/her operation, which suggests that abnormally long operative times might constitute a proxy of fatigue. This raises questions about how smoothing surgeons work during the week in order to avoid overloaded surgical schedule, allowing them to have a better control of their own performance.

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