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Volume−outcome relationship in parathyroid surgery

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A R T I C L E   I N F O

Background: Since its first description, several studies have highlighted the role of the surgeon's experience in the outcome of parathyroid surgery, however, no uniform consensus exists regarding the minimum operative experience required for good surgical outcomes. This work aims to summarize the current data regarding the surgeon volume−outcome relationship for parathyroidectomy.

Methods: An electronic literature review identified 85 publications, and after study selection 11 were included. An additional nine publications were added based on reference review and inclusion of publications not initially captured.

Conclusions: There are insufficient data to dogmatically conclude a minimum number of cases required to achieve optimal surgical results. However, extrapolation from the inclusive studies support the conclusions that higher operative volumes improve cure rates and decrease the rates of complications, recurrent disease, and perioperative costs. Endocrine Surgery fellowships or mentorships may help prepare the less experienced surgeon for successful outcomes. Although reticent to offer firm minimal volume requirements, we have made suggestions in this manuscript.

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Background

Since Per Ola Granberg and the Stockholm Endocrine Surgery group together with the Nordic Surgical Association described the role of the surgeon's experience in the outcome of parathyroid surgery in the 1980s, several studies have highlighted this topic. No uniform consensus has been reached regarding the minimum numbers of surgeries for good surgical quality in primary, secondary, and re-operative hyperparathyroidism. The aim of this work is to summarize the current data about the surgeon volume—outcome relationship for parathyroidectomy in order to find the ideal surgeon for the patient.

Introduction

Forty years ago, Luft et al. examined the relationship between volume and outcomes in surgery and questioned if surgical care should be regionalized to optimize outcomes. Looking at 12 different procedures of varying complexity at 1498 hospitals and they found major differences in select procedures. For certain procedures, mortality rates were significantly lower in high-volume centers, while others showed no association between hospital volume and outcomes [1,2]. These data sparked significant interest, and over the last four decades numerous studies have evaluated this phenomenon.

Multiple studies show that patient mortality is decreased and outcomes improved when complex operations are performed at high-volume centers. This is true for many surgical procedures and no doubt is related to multiple factors, including several independent of the surgeon [3—5]. This is exemplified by high-risk surgeries requiring complex perioperative management, such as surgical treatment of cancers of the pancreas, lung, esophagus or colon. High-volume centers tend to be larger and likely have advanced resources including an array of specialists, advanced intensive care units, specialized operative and anesthesia teams, sophisticated blood banks, and the capacity to accommodate the most complex co-morbid conditions [5—7].

More commonly performed procedures, requiring less complex perioperative management, including vagotomy and cholecystectomy, did not show a relationship between hospital volume and patient outcomes [2]. However, several studies have shown that morbidity and mortality are decreased when the surgical providers have high operative volumes, independent of the volume of the center [6,8,9]. While intuitively logical, it has only recently been shown that increased surgical volume improves outcomes. This has contributed to surgical sub-specialization with the expectation that surgeons performing fewer types of procedures at higher volumes, develop advanced techniques, improved judgment, and thereby, enhanced outcomes.

Within Endocrine Surgery, a sub-specialty of general surgery, parathyroidectomy is cited as a procedure where surgeon experience appears to affect outcomes. However, there is no consensus on what volume of case experience is associated with improved outcomes. This manuscript summarizes current data regarding the volume—outcome relationship in parathyroid surgery.

Methods

Literature search strategy

An electronic literature review was performed on MEDLINE by using the medical subject headings "volume", "outcome", "parathyroid surgery" with the Boolean operator "and". The publications in English of the last forty years were systematically included.

Selection criteria

Clinical trials, reviews, meta-analyses, individual series, and comparative series that discuss or investigate operative outcomes, surgeon volume, or surgeon specialization related to parathyroid surgery were considered.

Study selection

According to the aforementioned strategy, 85 publications were identified. On initial review, 11 were excluded because they did not deal with human subjects or were not published in English. In the second stage, all titles and abstracts were reviewed and selected according to the criteria, resulting in exclusion of 50 abstracts. 24 publications were selected for further analysis. After examination of the full manuscript, 13 additional studies were excluded because the parathyroid-specific results were not mentioned, or there was no information regarding surgeon specialization, experience or volume. As this review is meant to discuss the surgeon volume—outcome relationship for parathyroid surgery, articles based on hospital volume without indication of surgeon volume, those with low power, and those with insufficient information regarding parathyroid-specific cases were excluded. In the third stage, nine additional publications identified by reference review in the identified studies and by the authors' knowledge of additional relevant publications were analyzed and included. The search and selection processes are summarized in Fig. 1.

Results

For this review, failure to achieve cure during a single operative intervention is considered a surgical outcome and is recorded as persistent disease, representing operative failure, not a complication of surgery. Surgical complications include temporary and persistent hypoparathyroidism, temporary and persistent recurrent laryngeal nerve injury, hematoma, and mortality. Persistent disease is defined as failure to achieve cure of hypercalcemia, or re-development of hypercalcemia within six months of surgery. Recurrent disease is defined by achievement of postoperative eucalcemia for at least 6 months prior to re-development of hypercalcemia. These classic definitions are likely to change, as they are inadequate in the setting of normocalcemic primary hyperparathyroidism. To prove cure in this subset of patients both serum calcium and parathyroid hormone (PTH) need to be measured.

The included articles are summarized in Table 1, with blank cells reflecting the absence of published data [8,10—29].

Parathyroid-specific outcomes

Four studies looked at a direct comparison between surgeon volume and parathyroidectomy outcomes. Stavrakis et al. [8] evaluated the effect of surgeon volume on clinical and economic outcomes for thyroid, parathyroid and adrenal surgery using cross-sectional hospital data from both inpatient and outpatient surgery in New York and Florida for a single year. They created six surgeon volume groups with a roughly equal distribution of cases, including those who performed 1—3, 4—8, 9—19, 20—50, 51—99 and 100 or more cases per year. These numbers represent endocrine, not specifically para-thyroid cases, but the parathyroid-specific data can be extrapolated. In total, 3412 parathyroid cases were performed in the study period and were more likely to be performed by high-volume surgeons. The overall complication rates were inversely related to volume, with complication rates from lowest to highest surgeon volume groups of 9.13%, 4.35%, 3.51%, 2.22%, 2.43% and 0.44%, respectively. Simply stated, the highest volume surgeons had the lowest complication rates. They also demonstrated a significant observed to expected complication ratio for both the lowest and highest volume surgeons. Those who performed 1—3 endocrine cases per year, had an observed to expected complication rate ratio of 1.82 for parathyroid cases, whereas, those who performed 100 or more endocrine cases per year had an observed to expected complication rate ratio of 0.25 in parathyroid cases.

Neychev et al. evaluated the outcomes of four parathyroid surgeons practicing in a community hospital in comparison to an expert endocrine surgeon from a high-volume academic center, to evaluate if a surgeon's operative volume is the most important factor affecting rates of cure and complications in parathyroid surgery [25]. They evaluated patients undergoing an initial operation for primary hyperparathyroidism (PHPT) over a 12 year period at a community hospital and a three year period at an academic institution. The surgeons at the community hospital had an annual parathyroid procedure volume of 17 ± 8 cases while at the academic institution the volume was 73 ± 26 cases. The rates of cure were 97% and 99%, respectively. In the community hospital group, six of 204 (2.9%)
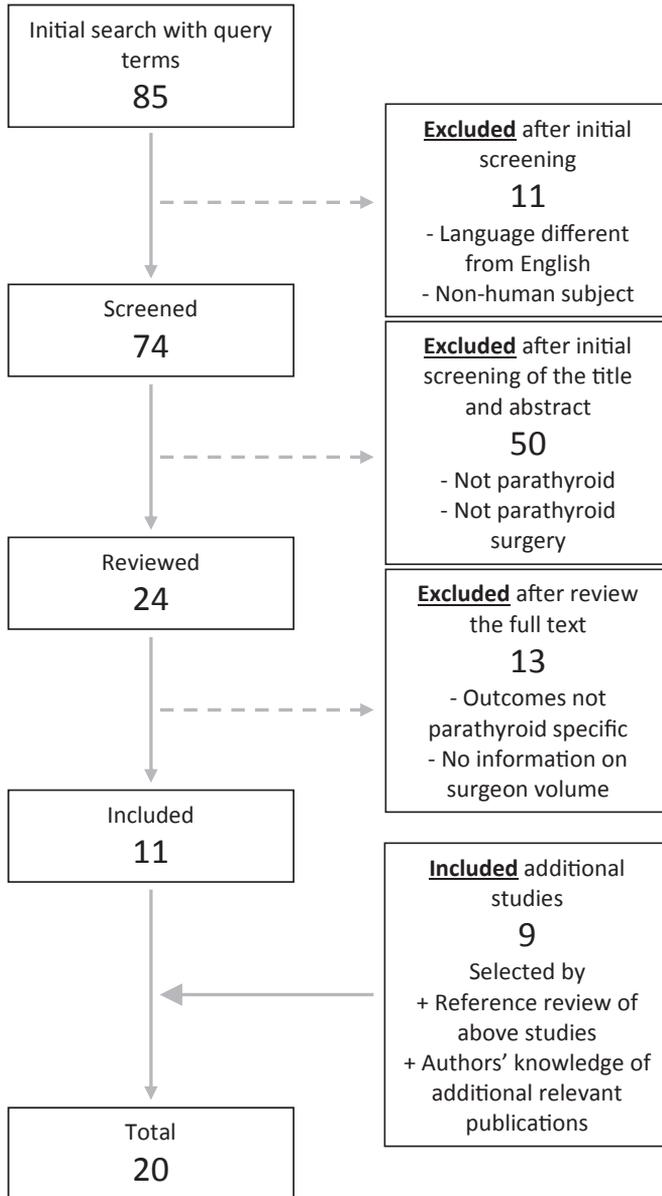
Fig. 1. Search and selection process.

patients required a second operation for persistent hyperparathyroidism, compared with two of 218 (0.9%) patients in the academic hospital group. Although there was a notable difference in the operative volumes between the two groups, both were considered experienced parathyroid surgeons and had high cure rates with minimal complications. They concluded that some of the magnitude of case volume difference was due to a referral pattern toward the high-volume center, but experienced surgeons achieve excellent results in either setting supporting the premise that surgeon volume outweighs hospital volume when analyzing parathyroid surgery outcomes.

Table 1
Parathyroidectomy outcomes and complications by surgeon volume and experience.

Author	Year	Cases	Procedure	Indication	Surgeon experience	Surgeon volume	Outcome	Complications
Farnebo [10]	1984	400 324 76	Parathyroidectomy	400 PHPT		>10 cases/10 yr <10 cases/10 yr	6.7% Persistent disease	7% Hypoparathyroid 0.8% Wound infection
Jaskowiak [11]	1996	222	Re-operative parathyroidectomy	222 PHPT 205 Persistent 17 Recurrent	Experienced Surgeons		94.1% Cure 13 Persistent disease	6 Temporary RLN injury 3 Permanent RLN injury 1 Marginal mandibular injury 42 Temporary hypoparathyroid 12 Permanent hypoparathyroid
Chen [12]	1996	169	Parathyroidectomy 149 Initial surgery 20 Re-operative	146 PHPT 23 SHPT/THPT	Endocrine Surgeon	169 cases/5 yr	97% Cure	1 Permanent hypoparathyroid 2 RLN injury
Shen [13]	1996	102	Re-operative parathyroidectomy		Endocrine Surgeon		95% Cure	1 Permanent RLN injury 1 Permanent hypoparathyroid
Sosa [14]	1998		Parathyroidectomy Self-reported outcomes		Endocrine Surgeons	<15 cases/yr 15–49 cases/yr >50 cases/yr	95.2% Cure initial 82.7% Cure remedial	1.91% Complication initial 3.76% Complication remedial 1.21% Complication initial 1.88 Complication remedial 0.99% Complication initial 1.48% Complication remedial
Low [15]	1998	866	Parathyroidectomy 813 Initial surgery 53 Re-operative	713 PHPT 100 THPT 53 Persistent/recurrent disease		866 cases/38 yr	7 Persistent disease	9 Permanent hypoparathyroidism 2 RLN injury 2 Mortality
Udelsman [16]	2002	656	Parathyroidectomy 401 Bilateral [72] Re-operative 255 Unilateral [12] Re-operative	656 PHPT 13 MEN 1 or 2A	Endocrine Surgeon	656 cases/11 yr	98% Cure	15 Any complication 4 RLN injury 2 Hypoparathyroidism 2 Hematoma
Bergenfelz [17]	2002	91	Parathyroidectomy 47 Unilateral 44 Bilateral	91 PHPT	Endocrine Surgeons		97% Cure 3 Persistent disease 3 Recurrent disease[a]	3 Temporary RLN injury 2 Temporary hypoparathyroid 1 Permanent hypoparathyroid

Table 1 (continued)

Author	Year	Cases	Procedure	Indication	Surgeon experience	Surgeon volume	Outcome	Complications
Udelsman [18]	2006	130	Re-operative parathyroidectomy		Endocrine Surgeon	1090 cases/15 yr	7 Persistent disease 2 Recurrent disease	4 Permanent hypoparathyroid 3 Permanent RLN injury 1 Stroke
Stavrakis [8]	2007	3412	Parathyroidectomy			1−3/yr 4−8/yr 9−19/yr 20−50/yr 51−99/yr 100+/yr		9.13% 4.35% 3.51% 2.22% 2.43% 0.44%
Chan [19]	2008	42	Parathyroidectomy 11 Unilateral 31 Bilateral	PHPT	Endocrine Surgeon	430 cases/5 yr	1 Persistent disease	None
Haciyanli [20]	2009	47	Parathyroidectomy 32 Unilateral 15 Bilateral	43 Sporadic PHPT 4 Familial PHPT			1 Persistent disease	1 Temporary hypoparathyroid
Udelsman [21]	2011	1650	Parathyroidectomy 613 Bilateral [135] Re-operative 1037 Unilateral [51] Re-operative		Endocrine Surgeon	1650 cases/19 yr	98.5% Cure	34 Any complication 14 RLN injury 4 Hypoparathyroid 3 Neck hematoma
Paravastu [22]	2012	368	Parathyroidectomy 49 Unilateral 319 Bilateral	368 PHPT		368 cases/11 yr	13 Persistent disease 2 Recurrent disease	5 Temporary RLN injury 1 Permanent RLN injury
Karakas [23]	2013	129	Re-operative parathyroidectomy	108 Persistent PHPT 17 Recurrent PHPT	Endocrine Surgeons	>100 parathyroid cases	92.2% Cure	20 Permanent hypoparathyroidism 10 Permanent RLN injury 6 Wound infections 2 Bleeding complications
Calo [24]	2013	175	Parathyroidectomy 154 Unilateral 21 Bilateral	175 PHPT	High experience in parathyroid surgery		3 Persistent disease	2 Temporary nerve injury 1 Hematoma 24 Temporary hypoparathyroid
Neychev [25]	2016	422	Parathyroidectomy	422 PHPT				
		204	112 Unilateral 86 bilateral 6 unspecified		4 Surgeons parathyroid/ thyroid trained	17 ± 8/yr	6 Persistent disease	1 Permanent hypoparathyroid 1 Wound infection
		218	147 Unilateral 66 bilateral 5 unspecified		1 Endocrine Surgeon	73 ± 26/yr	2 Persistent disease	1 Hematoma 1 Temporary hypoglossal nerve injury

Nicholson [26]	2016	126	Parathyroidectomy 52 Unilateral 73 Bilateral 1 Mediastinal	103 Sporadic PHPT 18 MEN 1 1 MEN 2a 2 Familial PHPT 1 FHH	Endocrine Surgeon	High-volume	94.6% Cure 6 Persistent disease 10 Recurrent disease	3 Temporary hypoparathyroid 3 Permanent hypoparathyroid 0 RLN injury
Meltzer [27]	2017	1094	Parathyroidectomy					
		547				>40 cases/yr		51 Any complication 1 RLN injury 9 Hypoparathyroid
		547				<20 cases/yr		59 Any complication 9 RLN injury 7 Hypoparathyroid
Dhillon [28]	2018	308	Parathyroidectomy 240 unilateral 68 bilateral	308 PHPT	3 Year high-volume	1580/12 yr		0 Permanent RLN injury 1 Temporary RLN injury

PHPT: primary hyperparathyroidism; yr: year(s); RLN: recurrent laryngeal nerve; SHPT: secondary hyperparathyroidism; THPT: tertiary hyperparathyroidism; MEN: multiple endocrine neoplasia; FHH: familial hypocalciuric hypercalcemia.

^a Noted on follow up study [29].

With the published data supporting an association between higher surgeon volume and better outcomes in thyroid surgery, Meltzer et al. [27] examined the association between volume and outcomes in parathyroid surgery. They compared a population of 2080 unique patients with a single parathyroid surgery performed over a 6 year period, by surgeons who performed either 20 or less or more than 40 parathyroid operations per year. They matched the cases to get a total of 547 matched pairs between the two groups. The study revealed excellent outcomes in parathyroid surgery without significant differences between the two groups. The overall rate of complications were comparable although slightly higher in the low-volume surgeon group at 10.8% compared to 9.3%. Rates of hypocalcemia were insignificantly higher in the high-volume surgeon group at 1.6% compared to 1.3%. The only complication that reached statistical significance was vocal cord paralysis which occurred with a rate of 1.6% in the low-volume, compared to 0.2% in the high-volume surgeon group. The high-volume surgeon group was also more likely to perform an outpatient procedure, 59.6% of cases, compared to 34.1%.

Sosa et al. [14] reported on outcomes in relation to surgeon volume, based on self-reported data from a survey of North American members of the American Association of Endocrine Surgeons. They demonstrated significant variation in physician decision-making for the surgical management of PHPT based on a surgeon's annual case load. The surgical outcomes also varied based on annual case load and when adjusted for years since training was completed. In general, regardless of years since completion of training, there was a significant difference in the complication rates after primary or remedial parathyroid surgery for those who perform less than 15 cases compared to those who perform 50 or more cases per year. While the reported complication rates were also higher for the intermediate group of 15−49 cases per year, neither adjusted nor unadjusted rates reached statistical significance. Regarding in-hospital post-operative mortality, the unadjusted rates reached statistical significance for both the low and intermediate volume groups at 1% and 0.73%, respectively, when compared to the high-volume group at 0.04% although the adjusted rate differences were not significant.

Dhillon et al. [28] is unique in their exploration of surgeon volume and outcomes. While the only outcome described is vocal fold paresis, this study evaluated a single surgeon and stratified risk over the course of years of practice. For parathyroid cases alone, the rate of injury was very low with only 1 injury in the total 374 cases performed over the study period for an injury rate of 0.3%. Looking at the cases overall, they showed the impact of years of practice on a single surgeon's cumulative operative experience. While this stratification did not separate out parathyroid cases, it did show a change in the rate of injury as a function of years of practice, with an overall mean of 2.9%, and the lowest nerve injury rate in the final two years of the study, at 1.1%.

In 2002, Udelsman published his series of 656 consecutive parathyroidectomies performed for PHPT over an 11 year period, inclusive of initial and re-operative cases [16]. The complication rate was 2.3% (15 cases) including four recurrent laryngeal nerve injuries, of which two were in re-operative cases, two post-operative neck hematomas, of which one patient was on chronic anticoagulation, and two cases of post-operative hypocalcemia. In this series, three patients (0.5%) developed recurrent disease, of which two were re-operative cases. Additionally, this series demonstrated a clear financial benefit of minimally invasive parathyroidectomy when compared to conventional exploration. Operative time, anesthesia time, and hospital length of stay were all decreased in the minimally invasive compared with the conventional group and each of these measures were associated with cost savings.

Expanding these data, in 2011 Udelsman et al. reported 1650 consecutive parathyroidectomies performed by a single high-volume surgeon over a 19 year period [21]. While the goal of the publication was to compare minimally invasive and conventional parathyroidectomy, it highlighted the parathyroid surgical outcomes for a single high-volume surgeon. It showed an overall 98.5% cure rate including both conventional and focused intervention with initial and remedial cases. The rate of complication was 2.1% overall with the rate of recurrent laryngeal nerve injury, neck hematoma, and post-operative hypocalcemia each below 1%. Separating by initial surgical intervention and re-operative surgery, the complication rates were 1.8% and 3.8%, respectively, consistent with other studies showing higher complication rates in re-operative surgery. This series also demonstrated decreased cost in parathyroid surgery when resources exist for a focused approach. In the minimally invasive subgroup, the mean length of stay was 0.2 days with a median of zero days, as 85% had outpatient surgery. In the conventional group, the mean length of stay was 1.3 days.

Re-operative parathyroid surgery has been evaluated independently in several series. Shen et al. [13] published a series of 102 patients who underwent re-operative parathyroidectomy for persistent or recurrent disease during a ten year period. Remedial surgery was curative in 95% of the cases. One patient had permanent post-operative hypocalcemia after surgery, and one had permanent vocal cord paralysis. Jaskowiak et al. [11] published a prospective study on 288 consecutive patients referred to the National Institutes of Health over a 13 year period, after at least one previous neck exploration for PHPT at another institution. After excluding 66 patients due to a diagnosis of parathyroid cancer, multiple endocrine neoplasia type 1 or non-familial multigland hyperplasia, they analyzed the remaining 222 patients believed to have single gland disease; 5% had three or more previous explorations, 17% had two previous exploration, and 78% had one previous exploration. The majority, 92%, had a previous failed operation(s) whereas 8% were initially cured, but developed recurrent disease six or more months after surgery. The re-operative success rate was 94.1% with 209 patients having a single successful exploration. Of the 13 operative failures, six underwent a second remedial operation during the study and were cured. The complications included six temporary and three permanent recurrent laryngeal nerve injuries, one permanent marginal mandibular nerve injury, three bleeds that required transfusion but not reoperation, and 61 cases of severe post-operative hypocalcemia. Of these 61 hypocalcemic cases, seven needed intravenous calcium, 42 required vitamin D supplementation, and 12 necessitated a delayed parathyroid autograft from cryopreserved tissue. The autograft function was not reported.

In 2006 Udelsman et al. [18] reported outcomes in 130 consecutive re-operative parathyroidectomies in 128 patients over a 15 year period. These patients included those with persistent PHPT after a failed exploration, recurrent PHPT, or newly developed PHPT in the setting of previous neck exploration such as thyroidectomy and was inclusive of patients with parathyroid carcinoma, multigland parathyroid hyperplasia, and familial hyperparathyroid syndromes. The previous interventions varied, but 13 had undergone two or more previous parathyroid explorations. In this series, the overall cure rate was 95% compared with 98% for the initial procedures performed in the same period. There were seven cases in six patients who failed to achieve cure during remedial exploration (5%). Of these, four had multigland disease, one in the setting of multiple endocrine neoplasia 2A with previously total thyroidectomy, and one patient had a supranummary gland. There were four complications: three recurrent laryngeal nerve injuries and one mild stroke.

Endocrine surgery outcomes not specific to parathyroid

Sosa et al. [30] found that in the case of thyroidectomy, those who performed >100 thyroidectomies during a five year study period had the lowest complication rate and shortest hospital stay. Adam et al. [31] reviewed hospital discharge data from the Health Care Utilization Project National Inpatient Sample data-sets for patients undergoing thyroidectomy to determine the threshold number of cases to determine a high-volume thyroid surgeon. Increasing surgeon volume was associated with decreasing odds of post-operative complications to the level of 26 cases per year. As such they used this as the designation of a high-volume thyroid surgeon for their analysis. Comparing low to high-volume surgeons, there was an odds ratio of 1.51 for overall complications, and a 12% increase in length of stay in the low-volume group.

Looking at both thyroid and parathyroid surgical outcomes together, Tuggle et al. [32] evaluated pediatric surgical outcomes. High-volume surgeons were defined as those who performed over 30 annual cervical endocrine cases and averaged 72 per year. When compared with pediatric and other surgeons performing the same cases on the same patient subgroup without overlap, the high-volume surgeons had an overall complication rate of 8.7% compared to 13.4% and 13.2%, respectively, and an endocrine specific complication rate of 5.6% compared to 11.0% and 9.5%, respectively. Other studies have shown comparable results and similarly do not delineate between thyroid and parathyroid cases [33,34].

Discussion

Due to the retrospective literature review technique employed and the lack of standardization in reporting, data analysis is problematic. The surgical indications for parathyroidectomy varied and were

not uniformly reported. There was no consistent method describing a surgeon's operative volume, level of experience or specialization, nor how outcomes and complications were reported. As such, synthesizing the published outcomes into a recommendation for ideal minimum prior parathyroid surgeon experience is challenging.

Considerations

The surgical approach and operative planning for hyperparathyroidism is heavily dependent on two major factors. Firstly, the underlying condition: sporadic PHPT vs. familial hyperparathyroidism vs secondary or tertiary hyperparathyroidism. As the pathophysiology varies, ideal operative management also differs significantly. Secondly, initial surgery is very different from remedial exploration. The goal of parathyroid surgery is to achieve a durable cure, normalizing serum calcium and PTH levels, without complications, especially nerve injury or permanent hypoparathyroidism. Navigating these issues relies on a surgeon's insight and skill.

PHPT is a common disorder due to excessive secretion of PTH from one or more parathyroid glands and 80–85% are caused by a single gland adenoma compared with 15–20% from multigland disease [35]. With single gland disease, the goal of surgery is to remove the offending gland without compromising the remaining glands or their blood supply. With multigland disease, generally, three and a half parathyroid glands are excised, leaving the patient with the equivalent of one normal gland. Pre-operative localization has expedited focused exploration, in single gland disease, however, quality imaging and intraoperative adjuncts to confirm adequate resection are required.

In secondary hyperparathyroidism, elevated PTH levels develop in response to chronic relative hypocalcemia, most often in the setting of end-stage renal disease. The parathyroid glands hypertrophy from chronic stimulation. In tertiary hyperparathyroidism, some patients with long-standing secondary hyperparathyroidism, develop autonomous parathyroid function manifested by hypercalcemia, or continue to have elevated PTH levels after kidney transplantation and develop hypercalcemia. In these cases, the surgical approach differs from single gland disease because these patients usually have four gland hyperplasia and are also more likely to have supranummary glands.

Remedial parathyroid surgery for patients with persistent or recurrent disease, or those who have undergone previous surgery in the operative field pose additional challenges [36–38]. Parathyroid locations are variable and are often in close proximity to the recurrent laryngeal nerve. The glands are small, with a normal gland weight of approximately 30 mg and enlarged glands vary in size and can be difficult to locate. Scarring and fibrosis in the neck and mediastinum obscure visualization of both normal and abnormal parathyroid glands [38]. Additionally, these changes make identification of other structures and landmarks more difficult. As such, it is imperative to review the indications, previous operative and pathologic records, and optimize imaging prior to remedial surgery [39–41].

Weighing these concerns, what is the minimum surgeon volume experience required to optimize outcomes? Furthermore, is the optimal surgical volume achieved during residency, fellowship, initial independent years of practice, or in a mentorship program? The available data are limited by a dearth of studies showing a direct comparison of outcomes related to surgeon volume. The majority of studies show individual surgeon or small group series and the measured outcomes of cure (short-term and long-term), recurrence, and complications vary significantly. In general, it can be extrapolated, that the higher a surgeon's volume, the better the cure rate, and lower the complication rate.

Specialization and training

In 1979 and 1980 surgeons with interest in the surgical management of endocrine diseases founded the International Association of Endocrine Surgeons and the American Association of Endocrine Surgeons [42]. Subsequently, several other societies emerged with a similar focus including those in Europe, Australia, and Asia [42–48]. Post residency training in Endocrine Surgery exists as fellowships throughout the world, in part to develop the requisite skills to become proficient parathyroid surgeon. However, programmatic operative experience varies greatly. The American Association of Endocrine Surgery fellowship standards require a minimum of 30 parathyroidectomies and 125 total endocrine cases during a 1–2 year fellowship. Individual programs in the United States, that quoted case numbers

for fellows, range from 60 to 150 parathyroid cases per year and overall endocrine surgery annual case numbers from 150 to greater than 500 [42]. The European Union of Medical Specialists has a curriculum and syllabus for requirements for board certification of the Division of Endocrine Surgery for both General Endocrine Surgery and Neck Endocrine Surgery. For both groups, within the three years prior to applying for the exam, applicants must have performed 15 and assisted in 20 parathyroidectomies for hyperparathyroidism, including at least 10 bilateral explorations [45]. This suggests that participating in around 30 parathyroid cases during the final years of training allow for adequate experience to become proficient in the independent practice of parathyroid surgery.

Operative volume

Within Endocrine Surgery, previous studies have examined the effect of surgeon experience on outcomes after thyroidectomy including analyses evaluating the minimum threshold of case volume to optimize surgical results. With regard to parathyroid surgery, four studies offered a direct comparison between surgeon volume and outcomes but differed significantly on surgeon volume stratification. They demonstrated improved outcomes with increased surgeon volume but there was no clear volume threshold elucidated. Self-reported survey data can be extrapolated to support the ideal parathyroid surgeon is one who performs 50 or more cases per year [14]. However, most of the end points did not reach statistical significance for the intermediate group, and those who perform 15 or more cases per year have comparable results to those performing 50 or more. This suggests that surgeons who perform between one to two cases a month and those who perform one or more cases per week approach equivalency in outcomes.

Stavrakis et al. [8] analyzed results of parathyroid surgery based on surgeon volume. The highest volume surgeons, performing over 100 endocrine cases per year, had a better outcome profile when compared to any of the lower volume groups. On close analysis, however, this simplicity is muddied. The complication rates were similar for those performing 20−50 and 51−99 endocrine cases per year, and were actually higher for those in the 51−99 case group. Thus, this report suggests a surgeon volume of 100 or more annual cases is ideal, but 20 cases or more is sufficient. Neychev et al. [25] discussed surgeons performing around 17 versus 73 parathyroid cases a year and concluded adequate results in both groups although there was a slightly higher failure rate in the lower volume group. This leans toward the determination that an annual parathyroid volume of 15−20 cases is sufficient.

Perhaps the most revealing information regarding outcomes in parathyroid surgery are reported in the published individual series. These are greatly skewed to high-volume parathyroid surgeons. Even in these series, the volume of parathyroid surgery varies greatly, all with excellent results. Averaging volumes, rates vary from 23 to 87 parathyroid cases per year, and approximately 10 re-operative cases per year. As these publications cite data from some of the most experienced parathyroid surgeons, one could argue these are the ideal values, however the volumes vary widely and it may be unreasonable to impose these volume suggestions upon the majority of surgeons performing parathyroid surgery.

A related topic is the avoidance of re-operation in parathyroid surgery [13,23,49−51]. The operative cure rate is highest and complication rate lowest during initial surgical intervention, whether focused unilateral or bilateral exploration. Thus, it is imperative to maximize initial cure rates and minimize remedial surgery. Operative failure in the setting of an appropriate drop in intraoperative PTH, unexpected ectopic parathyroid glands either undescended or mediastinal and not accessible through a cervical approach, and persistent hyperparathyroidism due to supranummary glands with identification of four parathyroid glands during the initial operation may be considered unavoidable. Recurrent disease is not attributed to failure of the previous operation. Alternatively, missed glands in normal locations, persistent hyperparathyroidism in multiple endocrine neoplasia, secondary or tertiary hyperparathyroidism after an inadequate subtotal parathyroidectomy, remedial surgery without sufficient preoperative localization, or persistent disease after focused exploration without localization or utilization of intraoperative PTH measurements are all considered avoidable reasons for persistent disease and reoperation [49]. Karakas et al. [23] reported 69% of parathyroid glands removed during re-operative surgery were found in a normal anatomic position. Mitchell et al. [49] report 22% of re-operative parathyroid cases referred from a high-volume center compared with 78% of those from

low-volume centers were avoidable. While these numbers are skewed and reported from major referral centers, they emphasize that inadequate initial surgeries are often avoidable.

Peri-operative adjuncts

Surgeon operative volume is not an isolated measure. Increased surgeon and hospital-volumes are associate with additional resources. For PHPT, a focused approach is expedited by accurate pre-operative localization. Imaging modalities are not equal in sensitivity or specificity and vary greatly in different centers. Ultrasound can be extremely useful but is operator-dependent. Other localization techniques, such as four dimensional computed tomography, magnetic resonance imaging, and sestamibi scans, while technically less operator dependent are not equivalent across centers due to differing protocols, scanners, and interpretative skills. This leads to significant variability in the quality and utility of individual studies. A parathyroid surgeon needs to be adept at evaluating studies for localization and quality. Additional localization techniques, including pre-operative parathyroid aspiration with PTH analysis and selective venous localization, are particularly useful adjuncts reserved for complex remedial cases. Also, a near real-time PTH assay when available for intraoperative use is one of the most utilized and effective adjuncts to optimize outcomes.

Limitations

The lack of sufficient and standardized outcome measurements limits our ability to make dogmatic conclusions. Additionally, this review does not examine the depth of other surgical experience related to parathyroid surgery. Specifically, extensive experience in thyroid surgery no doubt carries over to parathyroid cases. Furthermore, the data are often reported as annual cases and do not reflect a surgeon's cumulative career experience. Finally, it is likely that group experience extrapolates, at least to some extent, to individual outcomes.

Conclusions

The recommendations based on these limited data are not intended for use regarding licensing, credentialing, or legal proceedings. Our aims are to provide insights and suggestions to improve outcomes and guide referrals. Our overarching conclusion, is that there are a paucity of data and there are no publications demonstrating a consensus of the threshold case volume required to be an ideal parathyroid surgeon. However, based on the data presented, and following discussions with the most experienced endocrine surgeons in the world, the following suggestions are made: 1. For initial parathyroid exploration, an independent surgeon should have a cumulative operative history of a minimum 30 parathyroid cases with the ideal being 60 or greater; 2. For remedial parathyroid exploration, a minimum previous experience of 15 cases, with and ideal being 30 or more. We recognize that many surgeons may not have attained these volumes. It is suggested that they collaborate with more practiced colleagues. It is also recommended, particularly for remedial cases, given the higher complication and failure rates, if one does not have the cumulative experience or available support, it is advisable to refer these patients to a high-volume surgeon.

Summary

Parathyroidectomy is cited as an operation where the surgeon's experience appears to affect surgical outcomes, however, no consensus exists on what minimum surgeon volume is ideal. There is a dearth of data providing outcomes to determine the minimum numbers of cases necessary to be a successful parathyroid surgeon. Few studies discuss direct comparisons, there are significant differences in data abstraction, and all have non-standardized definitions of surgeon experience. In general, operative success rates in both primary and remedial parathyroid surgery improve and complication rates decrease as surgeon volume increases. Increased surgeon volume is also associated with decreased cost and the need for reoperation. The initial parathyroid surgery is safest and most likely to achieve a durable cure. Remedial surgery has higher failure and complication rates, however, with the

most experienced surgeons, success rates in remedial exploration approach that of primary intervention. Acknowledging the paucity of primary data, we suggest a minimal cumulative case volume of 30 previous parathyroid surgeries for an initial parathyroid exploration and 15 previous remedial explorations for re-operative parathyroid cases. While fellowships and mentorships are not standardized, they enable surgeons to become more proficient prior to independent explorations. Further investigation is required to substantiate these recommendations and to delineate the relationships between cumulative and annual surgeon volume experience and outcomes in parathyroid surgery.

Conflict of interest statement

The authors have no financial or personal disclosures.

Practice points

- Individual surgeon operative volumes and experience matter, as increased volumes are associated with improved cure rates, decreased complications, decreased operative failure, and decreased cost in parathyroid surgery.
- Peri-operative adjuncts and resources are important to maximizing surgical success rates including imaging modalities, parathyroid hormone assays, and venous localization capability.
- Endocrine Surgery training is not standardized but fellowships are available and mentorships can be utilized to help surgeons become proficient in parathyroid surgery.

Research agenda

- Randomized prospective trials comparing surgeon volumes and outcomes in parathyroid surgery.
- Longitudinal studies looking at annual surgeon volume—outcome relationships and cumulative surgeon volume—outcome relationship.
- Surgical trainee case log registration with standardized abstraction and follow-up requirements.

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