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The evolution of kidney surgery for renal masses in Switzerland – a retrospective analysis

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Summary

INTRODUCTION: According to international guidelines, partial nephrectomy is recommended as the standard of care in patients with cT1 kidney tumours, as well as in those with cT2, whenever technically feasible. Furthermore, due to the numerous advantages of minimally invasive techniques, the laparoscopic approach has been increasingly used worldwide. Our aim was to investigate the evolution of kidney surgery and to evaluate whether urologists adhere to these guidelines. Furthermore, we assessed the uptake of minimally invasive techniques in Switzerland over the past decade (observational period 2008–2020).

MATERIALS AND METHODS: Datasets were provided by the National Agency for Cancer Registration (NACR) and the Swiss Federal Statistical Office (FSO). The national cancer registry dataset was used to analyse age categories, gender, demographics, year of intervention, T-stage, and which surgical method (partial vs radical nephrectomy) was performed as the primary outcome. The data from FSO included information on the surgical approach (laparoscopic vs open) as the secondary outcome, including mortality. The age-standardised incidence rate (ASIR) was computed per 100,000 population, standardised to the European Standard Population. This study was conducted as an exploratory retrospective analysis, and results should be interpreted within this framework. Statistical analysis was performed using R.

RESULTS: The national cancer registry dataset included 10,810 patients with kidney tumours from 2008 to 2020. During this period, the ASIR (age-standardised incidence rate) of kidney tumours in Switzerland increased more than threefold, from 3.0 to 9.6 cases per 100,000 population. A total of 6,565 patients (60.7%) with kidney tumours were included in the analysis. The highest incidence of surgical treatment occurred among patients aged 65–69 (n = 1,081). However, during the observation period, cancer registration coverage of the Swiss population increased from 60% in 2008 to 100% in 2020. As the primary outcome, the relative number of partial versus radical nephrectomy overall increased from 23.2% (n = 48) in 2008 to 48.0% (n = 393) in 2020. In patients with pT1 tumours, a total of 2,457 partial nephrectomies (59.6%) were performed compared with 1,667 radical nephrectomies (40.4%) during the observation period. The FSO dataset included 10,700 patients with kidney tumours between 2008 and 2018. As the secondary outcome, the ratio of laparoscopic procedures compared with open procedures increased from 21.1% (n = 194) in 2011 to 45.2% (n = 485) in 2018. Regional differences were identified, especially regarding the relative number of partial nephrectomy procedures performed. Although the T-stage distribution at the time of diagnosis did not differ between genders, a slightly higher proportion of men (43.0%, n = 4,669) underwent partial nephrectomy compared to women (40.6%, n = 1'896). Overall mortality was low, with 0.7% in partial nephrectomy (n = 13) versus 1.3% in radical nephrectomy (n = 96) procedures, regardless of the surgical method.

CONCLUSION: Our study highlights a distinct increase in laparoscopic surgery (presumably robot-assisted) and partial nephrectomy for the treatment of kidney tumours during the past decade in Switzerland, suggesting adequate adherence to international guidelines. Further research is needed to analyse demographic and regional differences.

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Introduction

Advances in and increasing availability of imaging technologies, such as ultrasound (US) and computed tomography (CT), have significantly increased the detection of incidental kidney tumours [1, 2]. Furthermore, the global rise in obesity and hypertension, along with the ageing population, has led to a steady increase in renal cell cancer (RCC) incidence worldwide over the past decades [2, 3]. Hence, effective, evidence-based management of renal masses is essential.

Surgical resection in the form of elective partial nephrectomy provides favourable long-term outcomes for small, localised RCC, preserving renal parenchyma without affecting survival rates [4]. Partial nephrectomy offers benefits that are critical for preserving long-term renal function [5]. Since approximately the start of the new millennium, international guidelines have recommended partial nephrectomy as the standard of care in patients with cT1 tumours. For cT2 tumours, partial nephrectomy is advised whenever technically feasible, as it has been associated with comparable oncologic outcomes to radical nephrectomy in surgically resectable masses [6–9]. This supports the shift towards less invasive surgeries aimed at preserving renal function while safely managing localised RCC from an oncological perspective.

In addition to preserving more renal parenchyma, the use of less invasive approaches and significant advancements in surgical techniques have reshaped the landscape of RCC treatment [10]. Minimally invasive techniques, such as laparoscopic and robotic-assisted surgery, are associated with reduced perioperative morbidity, shorter hospital stays, faster recovery times, and equivalent oncological outcomes compared with open surgeries [11, 12]. Robot-assisted laparoscopic partial nephrectomy has similar oncologic and functional outcomes to open partial nephrectomy, along with improved perioperative outcomes and fewer complications compared with laparoscopic approaches, especially in patients with complex renal tumours [13].

This study aimed to analyse developments in renal cancer surgery over the past decade in Switzerland using datasets provided by the National Cancer Registry (NACR) dataset and the Swiss Federal Statistical Office (FSO), with a focus on the surgical method (partial vs radical nephrectomy) and the choice of surgical approach (laparoscopic vs open). This retrospective analysis aims to provide insights into the surgical treatment of RCC and to identify areas where practice may deviate from established guidelines, potentially guiding future improvements in RCC management in Switzerland.

Materials and methods

Data sources, dataset variables, and outcome measures

This retrospective study analysed all cases of patients aged over 18 years who were diagnosed with kidney tumours and registered in the cantonal cancer registries submitted to NACR for inclusion in the national cancer registry dataset, covering the period between January 2008 and December 2020. All patients who underwent surgical treatment with either partial or radical nephrectomy were included (for ICD-10 and CHOP codes, please see tables S1 and S2 in the appendix). Patients were excluded if they lacked essential data such as tumour staging or treatment type, as were patients receiving rare (n <3) or unconventional treatment modalities (i.e. percutaneous ablation) other than partial or radical nephrectomy (n = 84, 1.3%). A selection chart illustrating the inclusion and exclusion criteria can be found in tables S9 and S10 in the appendix. These criteria ensured a consistent and comprehensive dataset focusing on standard surgical treatments in patients with kidney tumours.

To obtain details on the surgical approach, a dataset from the Swiss Federal Statistical Office (FSO) covering the period from January 2008 to December 2018 was used. At the time of retrieval, data were only available up to 2018. These datasets (FSO dataset names: H.1.5. – H.1.10) provided aggregated data by year on the proportion of laparoscopic versus open surgeries, as well as mortality rates. Furthermore, the datasets included variables such as gender, region (7 major regions of Switzerland according to the FSO), year of intervention, age category (in 5-year intervals), diagnosis (ICD-10 codes: C64 and D41), cTNM, pTNM, type of treatment (partial or radical nephrectomy), and treatment intention (curative or palliative).

It is important to note that the NACR and FSO datasets were generated and analysed independently. The NACR dataset focuses on patient diagnosis and treatment details, while the FSO dataset provides specific information on surgical approach and outcomes. As the primary outcome, the absolute and relative increase in partial nephrectomies versus radical nephrectomy according to T-stage was defined. The surgical technique (laparoscopic vs open) was specified as the secondary outcome. The study was conducted as an exploratory analysis describing operative trends in the surgical treatment of kidney tumours to evaluate adherence to international guidelines.

Data classification and analysis

The trends in surgical methods (partial vs radical nephrectomy) and approaches used (laparoscopic vs open) were analysed over the 12-year observation period. In the NACR dataset, treatments were classified according to CHOP codes [14]. CHOP codes indicating the radical nephrectomy surgical method were aggregated, and the same approach was used for partial nephrectomy. Additionally, the medical hospital statistics from the FSO allowed the analysis of trends in surgical approaches (laparoscopic vs open). Potential associations between treatment type and variables such as tumour stage, patient gender, age category, and region were explored separately in each dataset. The aim was to enable a comprehensive analysis of treatments and changes in treatment preferences over time.

Statistics

Descriptive statistics were used to summarise the clinical characteristics of the patient cohort, stratifying data by treatment type and other variables, such as age categories, gender, region, year of intervention, T-stage, and mortality rates. Covariables were selected based on their clinical relevance and their potential influence on surgical decision-making, as well as to account for temporal and regional variation in treatment practice. Graphical visualisations were plotted to illustrate trends in partial versus radical nephrectomy ratios over time, as well as changes in the choice of laparoscopic versus open surgical approaches. Univariable logistic regression models were used to calculate the odds of receiving partial nephrectomy by increasing T-stage. Furthermore, univariable and multivariable logistic regression models were employed to analyse the data, assessing the association between the surgical method (binary outcome of either partial or radical nephrectomy) and the predictor variables, such as age category (0–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, and ≥85 years), pT-stage, gender, region, and treatment year. The models were fitted using a logit link function. P-values below the 0.05 level were considered statistically significant. Odds ratios (OR) were calculated and are presented with 95% confidence intervals (CIs).

The age-standardised incidence rate (ASIR) was calculated for each year of observation using the direct standardisation method and the 2013 European standard population [15]. This standardised measure considers differences in the age distribution of the population, allowing for comparison over a longer period, regardless of demographic changes.

Data entry, processing, and statistical analysis were performed using R Studio (Version 2023.09.1+494. 2023) [16].

Ethics and regulatory compliance

Ethical approval for this study was obtained from the local ethics committee (Kantonale Ethikkommission Kanton Zürich, BASEC-Nr. Req-2021-00479). Throughout the observation period, cancer registration in Switzerland was regulated at a regional level, and reporting to the NACR was optional until 2019. Previously, only cantons with a registry were able to report data with 100% coverage to the NACR. Thus, before 2020, the national cancer registry dataset did not cover the entire country of Switzerland, and information on treatment and other variables may have been incomplete.

Protocol and registration

No prospective study protocol was prepared for this retrospective, exploratory analysis. The study was conducted using pre-existing datasets (NACR and FSO), and all analyses were performed post hoc. Consequently, the study was not registered in any public registry, and there were no protocol deviations to report.

Results

Cohort

From 2008 to 2020, a total of 10,810 patients with kidney tumours were recorded in the NACR database. All 10,810 patients underwent a form of therapy. However, information on the type of therapy and tumour staging was only available for 6,565 patients. Therefore, only these patients

(60.7%) were included in the final analysis, after excluding cases with missing data and rare or unconventional treatment modalities. The FSO dataset included data from 2008 to 2018 for 10,700 patients. It had already been filtered for missing values, ensuring that all available data on laparoscopic and open procedures could be included in the analysis. The reported figures increased in both datasets as the years progressed. Patient characteristics of the study population from the national cancer registry dataset during the observation period, including the total number of interventions, the most common age category of onset, gender, T–stage distribution, and region, are presented in table 1.

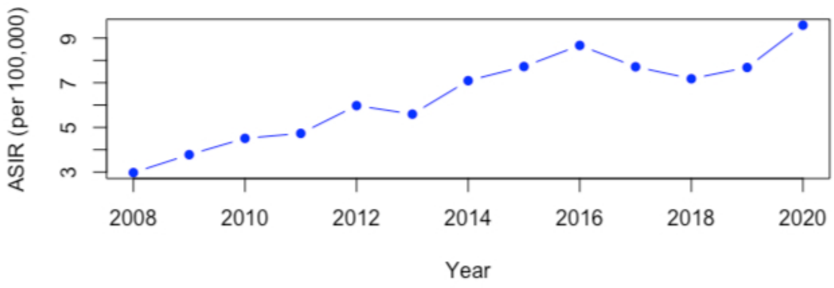
Table 1: Patient characteristics of the study population from the NACR dataset.

Patient characteristics		**Partial nephrectomy n (%)**	**Radical nephrectomy n (%)**
Age	0–44	210 (54.5)	175 (45.5)
	45–49	169 (48.3)	181 (51.7)
	50–54	283 (49.4)	290 (50.6)
	55–59	356 (49.6)	362 (50.4)
	60–64	398 (42.7)	533 (57.3)
	65–69	504 (46.6)	577 (53.4)
	70–74	419 (40.6)	613 (59.4)
	75–79	333 (38.0)	543 (62.0)
	80–84	124 (26.0)	353 (74.0)
	85+	25 (17.6)	117 (82.4)
Gender	Female	770 (40.6)	1126 (59.4)
	Male	2051 (43.9)	2618 (56.1)
Year of intervention	2008	48 (23.2)	159 (76.8)
	2009	54 (20.4)	211 (79.6)
	2010	95 (29.2)	230 (79.8)
	2011	122 (35.4)	223 (64.6)
	2012	166 (37.6)	275 (62.4)
	2013	159 (37.2)	268 (62.8)
	2014	234 (42.5)	316 (57.5)
	2015	278 (45.4)	334 (52.6)
	2016	331 (47.6)	364 (52.4)
	2017	314 (49.9)	315 (50.1)
	2018	287 (48.0)	311 (52.0)
	2019	340 (52.2)	311 (47.8)
	2020	292 (47.9)	427 (52.1)
Pathological T-stage	pT1a-pT1b	2457 (59.6)	1667 (40.4)
	pT2a-pT2b	96 (15.2)	536 (84.8)
	pT3a-pT3c	203 (12.7)	1396 (87.3)
	pT4	2 (3.1)	62 (96.9)
	notknown	23 (39.0)	36 (61.0)
Region	LakeGenevaregion	446 (43.4)	582 (56.6)
	Midlands	549 (45.8)	650 (54.2)
	NorthwesternSwitzerland	240 (43.8)	312 (56.2)
	EasternSwitzerland	527 (43.1)	696 (56.9)
	Ticino	149 (25.0)	448 (75.0)
	CentralSwitzerland	232 (49.5)	137 (50.5)
	Zurich	678 (45.3)	819 (54.7)

Age-standardised incidence rates

The ASIR of kidney tumours increased steadily from 2.97 per 100,000 residents in 2008 to 9.58 per 100,000 residents in 2020. Therefore, our calculations are in line with the ASIR of 9.7 reported by the Global Cancer Observatory for the year 2022 [17]. This trend reflects, with some fluctuations, a more than threefold growth in incidence during the observation period (figure 1).

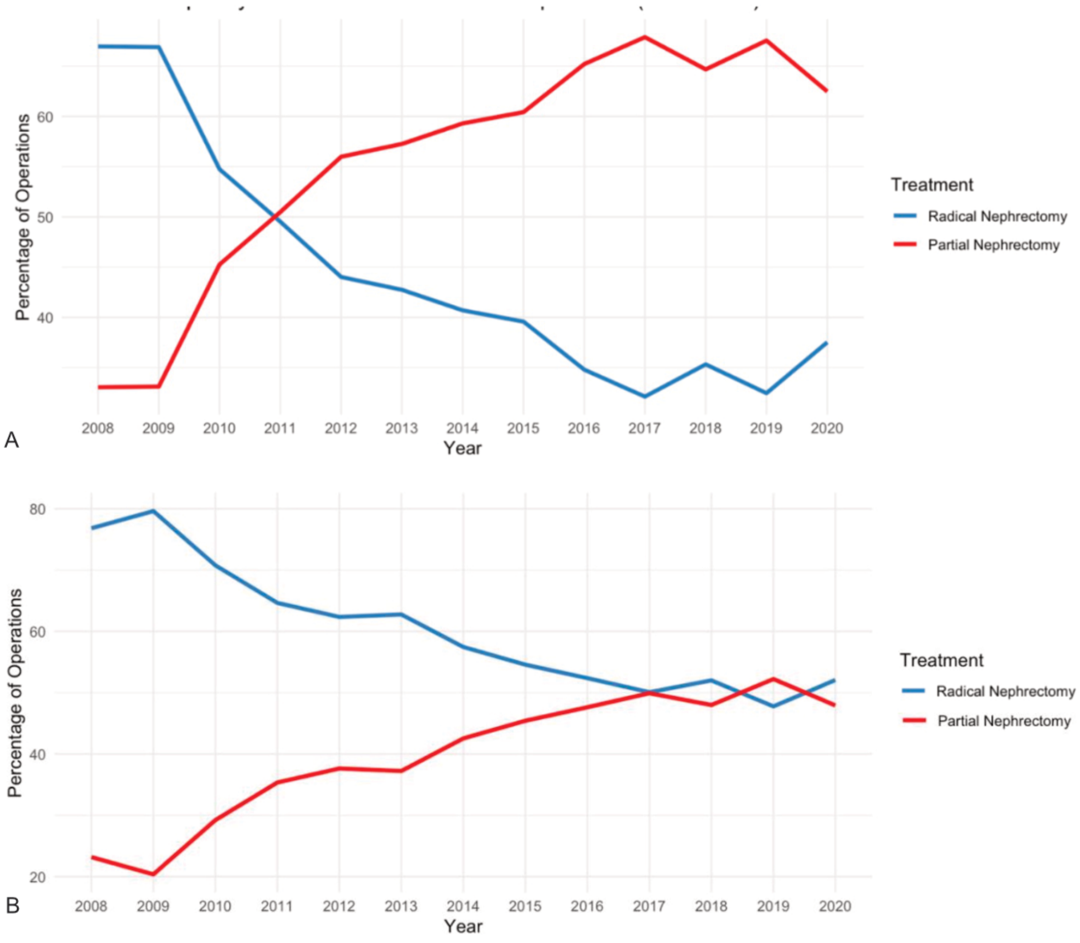
Figure 1: Age-standardised incidence rate (ASIR) for RCC during 2008–2020.



Surgical interventions

The largest group was patients with surgically treated kidney tumours aged 65–69 years (n = 1,081). During the observation period, a total of 2,821 (43%) partial nephrectomy and 3,744 (57%) radical nephrectomy procedures were documented. Figures 2a and 2b illustrate the primary outcome, showing the increasing proportion of partial nephrectomies compared with radical nephrectomies performed for kidney tumours from 2008 to 2020, stratified by all T-stages and the pT1 stage. The absolute number of documented surgical interventions in patients with kidney tumours increased fourfold, from n = 203 in 2008 to n = 814 in 2020. The proportion of partial nephrectomies compared with radical nephrectomies increased markedly over the observation period (figure 2a). In patients with pT1 tumours, the increase in partial nephrectomies compared with radical nephrectomies was even more pronounced. In 2011, partial nephrectomy exceeded radical nephrectomy in patients with pT1 tumours for the first time, and the gap increased each year thereafter (figure 2b). Univariable regression analysis revealed the treatment year as a significant predictor of receiving partial nephrectomy among patients with pT1 tumours (OR = 1.09, 95% CI: 1.075 to 1.11, p <0.001). This association persisted after adjustment for age and gender, with no relevant change in effect size (table S3 in the appendix). Regarding the secondary outcome measure, based on the 10,700 nephrectomy procedures in the FSO dataset, most radical nephrectomy procedures were performed via an open approach, accounting for 53.7% of surgeries (n = 5,748). Laparoscopic radical nephrectomies only accounted for 13.2% (n = 1,410). Partial nephrectomy using an open approach accounted for 21.4% (n = 2,288), while 11.7% (n = 1,254) were performed laparoscopically. Figure 4 reflects the overall distribution of surgical approaches among all procedures included in the dataset from 2008 to 2018.

Figure 2: A: Proportion of partial nephrectomies versus radical nephrectomy across all T-stages (2008–2020). B: Proportion of partial nephrectomies versus radical nephrectomy in pT1 tumours (2008–2020).



Tumour stage, age, and treatment type

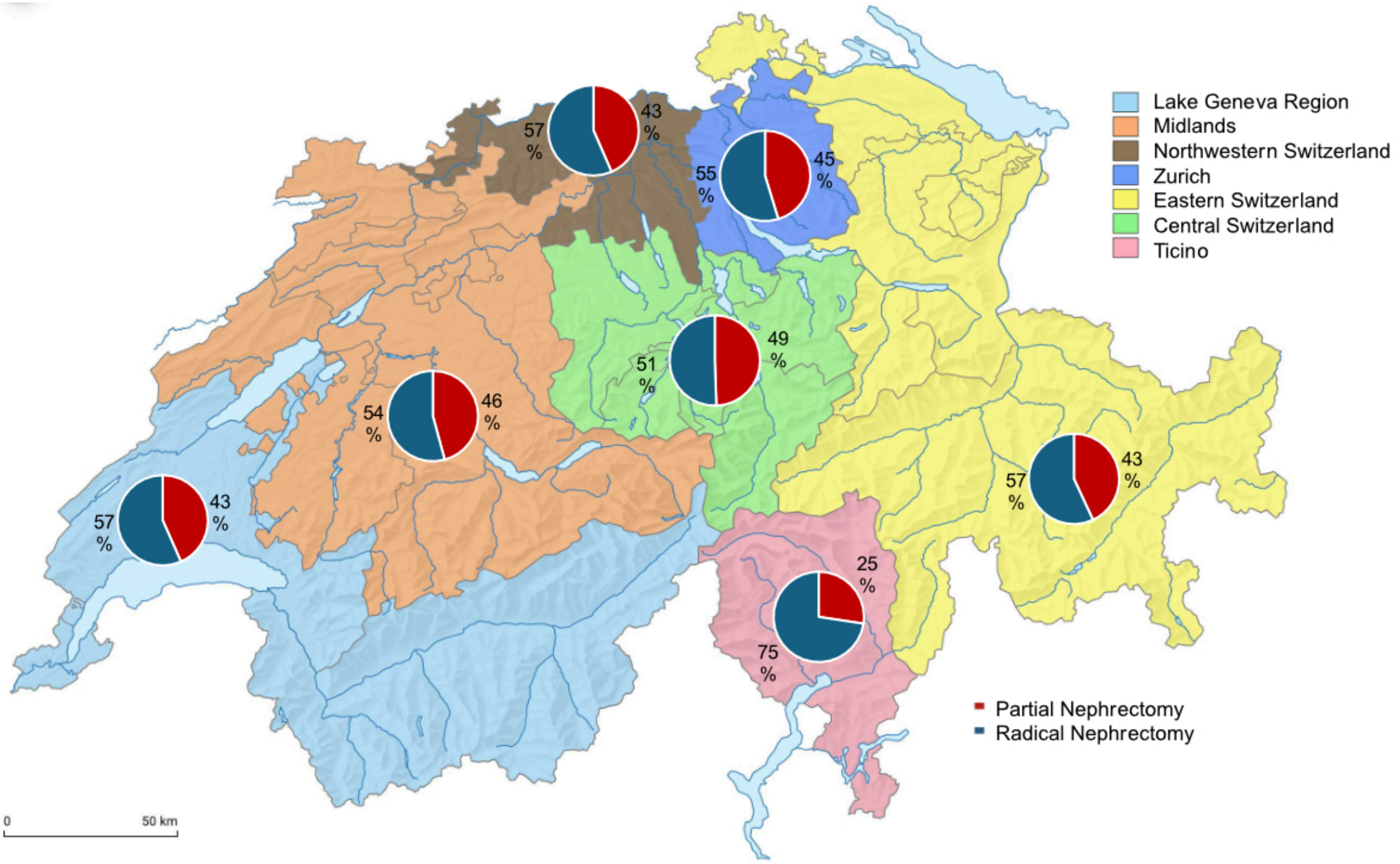
T-stage had a distinct influence on the choice of procedure. Among patients with pT1 tumours, a total of 2,457 partial nephrectomies (59.6%) were performed, compared with 1,667 radical nephrectomies (40.4%), whereas patients with pT2 and pT3 tumours underwent radical nephrectomy in most cases (n = 1,994, 86.9%; table 1). Results from univariable regression analysis demonstrate that with increasing T-stage, the likelihood of receiving partial nephrectomies decreases. Using pT1 as the reference group, the odds of receiving partial nephrectomies were significantly lower for higher T-stages: pT1 versus pT2 (OR: 0.12, 95% CI: 0.10 to 0.15, $p < 0.001$), versus pT3 (OR: 0.10, 95% CI: 0.08 to 0.12, $p < 0.001$), and versus pT4 (OR: 0.02, 95% CI: 0.01 to 0.09, $p < 0.001$). These associations remained essentially unchanged after adjustment for age and gender (all $p < 0.001$, see table A4 in the appendix).Similarly, age was also a relevant factor, as partial nephrectomies was used more frequently in younger patients. The difference became more distinct with increasing age, as older patients had a significantly lower probability of undergoing partial nephrectomies. In the youngest age subgroup (0–44 years), partial nephrectomies was performed in 54.5% of patients, whereas in the oldest age subgroup (85+ years), partial nephrectomies was performed in only 0.2% of cases. Furthermore, the age of the patients was correlated with T-stage: in the 0–44 age category, 71% of patients had a pT1 tumour. This proportion continuously decreased in older patients, reaching 45% in the 85+ age category. If a curative operation was intended, based on the tumour board decision, partial nephrectomies was performed in 47.7% of cases. By contrast, cytoreductive nephrectomy was performed in only 12.2% of palliative cases.

Regional differences

The 7 regions studied correspond to the NUTS-2 (Nomenclature of Territorial Units for Statistics) level units defined by Eurostat, the statistical office of the European Union: Lake Geneva region: Waadt, Wallis, and Genève; Midlands: Bern, Freiburg, Solothurn, Neuenburg, and Jura; Northwestern Switzerland: Basel-Stadt, Basel-Landschaft, and Aargau; Zurich: Zürich; Eastern Switzerland: Glarus, Schaffhausen, Appenzell A.Rh., Appenzell I.Rh., St. Gallen, Graubünden, and Thurgau; Central Switzerland: Luzern, Uri, Schwyz, Obwalden, Nidwalden, and Zug; and Ticino: Tessin.

Over the 12-year observation period, our analysis revealed that existing regional differences influenced the likelihood of receiving partial nephrectomies. Multivariable regression analysis adjusted for age and tumour stage demonstrated that in the region of Ticino, patients had a lower probability of receiving partial nephrectomies (OR: 0.36, 95% CI: 0.29 to 0.45, p <0.001), whereas patients in Central Switzerland had a higher probability of undergoing partial nephrectomies, even after adjusting for age and T-stage (OR: 1.7, 95% CI: 1.37 to 2.12, p <0.001). In both cases, the reference group comprised all other regions combined (i.e. the six remaining regions of Switzerland); this approach was applied consistently for all OR analyses comparing individual regions (see table S5 in the appendix). However, the significant difference did not account for other regions in Switzerland, such as the Midlands, Northwestern or Eastern Switzerland, or the Zurich and Lake Geneva regions. Overall, the total number of partial nephrectomies increased notably from 2008 to 2020 in all regions of Switzerland. The Zurich region exhibited the largest increase, from n = 4 documented cases in 2008 to n = 88 in 2020. Similarly, the Lake Geneva region also exhibited a steady rise in partial nephrectomies numbers, from n = 16 in 2008 to n = 73 cases in 2020, respectively. The Midlands peaked at n = 91 cases in 2016 and thereafter stabilised at n = 82 in 2020. Comparatively, Ticino showed a minimal growth, from n = 3 to n = 15 cases during our observational period, including the lowest proportion of partial nephrectomies (25%) compared with all other regions, corresponding to the NUTS-2 level units combined (45.4%) (figure 3). Northwestern and Central Switzerland started with the lowest number of partial nephrectomies cases, with n = 0 and n = 2 cases in 2008, respectively, which increased to n = 69 and n = 32 cases, respectively, by 2020. Interestingly, Eastern Switzerland peaked at n = 69 cases in 2019 and then declined to n = 34 in 2020. In 2020, the Zurich and Lake Geneva regions, as well as the Midlands, emerged as the leading regions for partial nephrectomies procedures performed, collectively accounting for n = 243 cases (52% of the total).

Figure 3: Geographical distribution of the partial nephrectomies versus radical nephrectomy ratio across regions in Switzerland (2008–2020). Map source: Swiss Federal Statistical Office (FSO); diagram elements added by the authors.



Gender-based differences

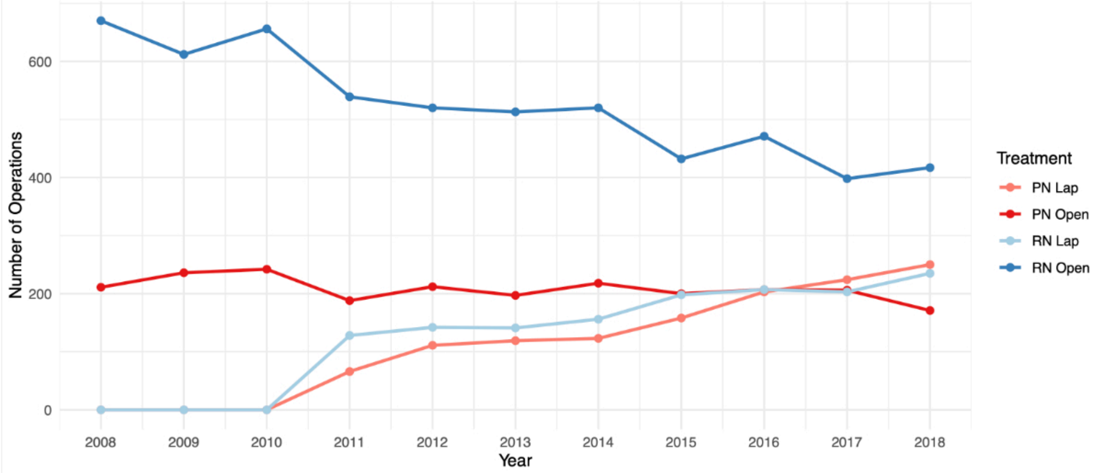
Overall, male patients had a slightly higher proportion of pT1 tumours at the time of treatment compared with female patients (64.5% vs 61.7%). Accordingly, the proportion of partial nephrectomies performed was also slightly higher in the male cohort (44.0% vs 41.1%). Univariable logistic regression revealed a statistically significant gender difference in favour of male patients undergoing partial nephrectomy (OR: 1.15, 95% CI: 1.03 to 1.28, p = 0.014, reference = female). After adjusting for age, region, and tumour stage, the previously observed association was no longer significant (OR: 1.10, 95% CI: 0.97 to 1.24, p = 0.15, reference = female) (see table S6 in the appendix).

To explore potential regional disparities in the use of partial nephrectomy, a multivariable logistic regression analysis stratified by gender was performed. In Ticino, the odds of receiving partial nephrectomy were significantly lower in both women (OR 0.31, 95% CI: 0.21–0.46, p <0.001) and men (OR 0.45, 95% CI: 0.36–0.56, p <0.001), compared with all other regions (table S7 in the appendix). In Central Switzerland, male patients exhibited a significantly higher OR of undergoing partial nephrectomy (OR 1.36, 95% CI: 1.09–1.71, p = 0.007), whereas no significant difference was observed among female patients (OR 1.26, 95% CI: 0.89–1.77, p = 0.19). For the remaining regions (Midlands, Northwestern Switzerland, Eastern Switzerland, and Zurich), no statistically significant associations were observed between region and partial nephrectomy in either gender.

Surgical approach and mortality

Along with the increase in partial nephrectomy over time, we observed a steady adoption of new surgical approaches, as reflected in the rising numbers of laparoscopic procedures. The proportion of laparoscopic procedures increased continuously over the observation period (figure 4). Overall, mortality was relatively low for both partial nephrectomy (mean 0.65%, range: 0.0–1.42%) and radical nephrectomy (mean 1.34%, range: 0.44–2.45%) procedures, regardless of the surgical method used.

Figure 4: Surgical approach, categorised as laparoscopic partial nephrectomy or open partial nephrectomy versus laparoscopic radical nephrectomy or open radical nephrectomy (2008–2018).



Discussion

Our study presents a comprehensive analysis of the development in surgical treatments for kidney tumours in Switzerland over a 13-year period. During the study period, international guidelines underwent significant changes, recommending nephron-sparing and minimally invasive surgery as the preferred treatment modalities not only for T1 tumours but whenever this is technically feasible. The data indicate that Swiss urologists are largely following international guidelines, with a substantial change in the operative management of RCC over the last decade. In patients with pT1 tumours, partial nephrectomy clearly became the preferred treatment option during the observed period. A shift, albeit a small one, towards partial nephrectomy was also seen in higher T-stages. Despite the increasing use of minimally invasive procedures, we found some differences among the different regions in Switzerland. Furthermore, our findings highlight several insights into the landscape of kidney tumour management, with particular emphasis on the increasing adoption of partial nephrectomies and laparoscopic techniques over the years, especially in patients with T1 tumours. Overall, the chance of receiving partial nephrectomy increased by 7.9% with each additional year, according to the analysis of the provided dataset. This trend aligns with the recommendations of international guidelines.

Interestingly, our data revealed a marked rise in the ASIR of kidney tumours during the observation period. The ASIR increased more than threefold over the observation period (figure 1). This trend reflects not only an increasing number of kidney tumour diagnoses but may also point towards improvements in early detection through more widespread use of imaging techniques, such as sonography, CT, and MRI, as well as the expansion of national cancer registration efforts [1]. The steady increase in ASIR underscores the growing relevance of RCC as a public health concern and reinforces the importance of adapting surgical practice to meet the needs of a changing epidemiological landscape. Nevertheless, part of the observed increase may also stem from enhanced reporting completeness, as cancer registration coverage in Switzerland rose from approximately 60% in 2008 to nearly 100% by 2020.

The shift towards partial nephrectomy is likely driven by its well-documented benefits in preserving renal function and achieving comparable oncological outcomes to radical nephrectomy [18]. However, radical nephrectomy still plays a role in selected patients, especially in conditions in which nephron-sparing surgery is neither indicated nor feasible [19]. International data reveal varying degrees of adherence to these guidelines. A study published in 2016 by Banegas and colleagues identified a significant shift in the United States towards a greater use of nephron-sparing and minimally invasive surgical approaches for RCC treatment [20]. Particularly in patients with pT1 stage, the rate of partial nephrectomies rose from 43% in 2004 to 55% in 2009 ($p \leq 0.05$), while laparoscopic partial nephrectomies increased from 8% to 15% during the same period. Following this, the rate of partial nephrectomies stabilised at around this proportion. In 2014, 57% of T1 tumours in the United States were managed with nephron-sparing surgery [21]. Other studies from overseas as well as in other European countries have reported similar trends towards an increasing use of partial nephrectomy compared with radical nephrectomy, particularly in tertiary care centres [22–25]. However, disparities exist, with some countries showing slower adoption rates, possibly due to differences in healthcare infrastructure, surgical expertise, and socioeconomic factors [23, 26]. Regional differences in the choice of partial nephrectomy were also found in a study conducted by Pyrgidis et al. in Germany, where patients in larger hospitals were more likely to undergo minimally invasive operative techniques [27]. Our findings of regional differences within Switzerland mirror these international trends, suggesting that efforts to standardise RCC management are already in practice, but with room for improvement. For example, the disparities in some regions may be attributed to the size of institutions, the availability of surgical expertise, and access to advanced surgical technologies such as robot-assisted procedures.Patel et al. observed an increasing adoption of robot-assisted partial nephrectomy in the U.S. between 2008 and 2011, reaching 14% in university hospitals and 10% in non-university hospitals ($p = 0.03$). This reference suggests that robot-assisted laparoscopic technology may help surgeons in different clinical settings to perform nephron-sparing surgery, irrespective of T-stage [24]. Addressing these discrepancies is crucial to ensure equitable healthcare delivery across the country.

Age and tumour stage emerged as significant factors influencing the choice of surgical method. This likely reflects the greater importance of long-term renal function preservation in younger patient cohorts with longer life expectancies, for whom higher perioperative risks are accepted; by contrast, in older patients, comorbidities, prior surgeries, and competing risks often shift management towards active surveillance or ablative strategies. Similar age-related treatment patterns favouring partial nephrectomy in younger patients have been reported in published research, even among patients with a comparable tumour stage (pT1) [28, 29]. According to our analysis, younger patients were considerably more likely to undergo partial nephrectomy, whereas its use declined sharply with increasing age. Accordingly, the increasing use of active surveillance in small renal masses, especially in elderly patients, must be accounted for [30]. It is important to note that T-stage played a pivotal role in the choice of surgical method, even after adjusting for age and gender. Furthermore, younger patients tended to be diagnosed with lower T-stages and were thus more likely to be treated with partial nephrectomy. A slightly higher use of partial nephrectomy was observed in male patients, which appeared to be largely explained by differences in tumour stage at presentation.

Finally, one notable trend found in our study was the increasing use of the laparoscopic approach, with the proportion of laparoscopic procedures increasing from 21.1% in 2011 to 45.2% in 2018. The published literature demonstrates that this shift is attributed to technological changes, with the broad availability of robotic-assisted techniques [24], benefiting patients through lower intraoperative blood loss, a shorter length of hospital stay, and a lower overall complication risk [31, 32]. These advantages make minimally invasive methods an appealing option for both patients and surgeons [33]. In terms of safety, our study demonstrated low intraoperative and in-hospital mortality rates for both partial nephrectomy (0.65%) and radical nephrectomy (1.34%), comparable to published international data [34]. These findings reinforce the feasibility and safety of both surgical approaches in the surgical management of kidney tumours.

Our study has strengths and limitations. The large size of our study population and population-based source of data is a clear advantage. However, the retrospective nature of the study and the use of two different datasets with a substantial number of missing data are potential sources of bias. Of the total of 10,810 patients in the national cancer registry dataset, only 6,565 (60.7%) could be included in the statistical analysis. This was mainly due to incomplete reporting of T-stage and/or treatment. Additionally, the observed population changed over time, with more registries contributing to better documentation and an improved dataset. This may have led to a higher number of registered patients with RCC; therefore, the increasing number of surgical procedures should be interpreted with caution, as well as the influence of surgical and technical progress over time, which may favour partial nephrectomy. However, diagnostic accuracy also improved with better ultrasound and more incidental findings due to the widespread use of CT and MRI scans. Furthermore, missing data and a lack of coding practices may have introduced bias, as we could not estimate whether patients received any or a different surgical treatment. This also had an impact on the calculated incidence rate. The calculated ASIR is slightly higher than the projections of the FSO for the entire population in all age groups. One explanation may be that calculations were performed on a regional and not on a cantonal level, and we had no data for patients included in the age group of <18 years. Both may partly explain the higher incidence observed. A technical aspect is the increasing number of robotic surgical systems installed throughout Switzerland, leading to a clear trend in favour of laparoscopic procedures over time. Finally, the data from the NACR and the FSO were collected independently and thus cannot be directly matched. These aspects highlight limitations in evaluating the Swiss healthcare system regarding centralised data collection through cancer registries before 2020. With the introduction of the Federal Act on the Registration of Cancerous Diseases in 2020 and a duty to report standardised information (e.g. treatment) for all diagnosed cancer cases in Switzerland, an important step to support analyses of the quality of care with real-world cancer registry data has been taken [35, 36]. Before 2020, cancer registration was not yet established in all cantons and was primarily used to monitor the development of cancer, which is why information on treatment was not systematically recorded.

Conclusion

Our study provides valuable insights into the evolving patterns of kidney tumour surgery in Switzerland, using cancer registry data and highlighting the increasing preference for laparoscopic partial nephrectomy (most likely robot-assisted) techniques. This development is largely influenced by patient demographics, tumour characteristics, regional practices, and adherence to international guidelines.

Data sharing statement

The original datasets of the National Cancer Registry (NKRS) and the Swiss Federal Statistical Office (SFO) are subject to legal restrictions and cannot be shared; however, access is available upon reasonable request.

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Appendix

Table 1: Number of Kidney Surgeries by ICD-10 Diagnosis (C64, D41) and Procedure Type, 2008–2020

ICD-10	Treatment	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
C64	Other kidney surgery	<3	<3	<3	<3	<3	<3	<3	<3	<3	3	4	45	32
C64	Partielle Nephrektomie	48	55	96	123	165	159	232	277	330	314	287	339	392
C64	Totale Nephrektomie	161	213	234	225	281	273	326	341	377	323	315	318	433
D41	Other kidney surgery	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
D41	Partielle Nephrektomie	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
D41	Totale Nephrektomie	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	3

Table 2: CHOP Codes for Kidney Surgery with Categorization for Analytical Purposes

CHOP-Codes	Code Beschreibung DE	Kategorie für Auswertungen
55.32	Offene Exzision von Läsion oder Gewebe an der Niere	OTHER_SURGERY_KIDNEY
55.34	Laparoskopische Exzision von Läsion oder Gewebe an der Niere	OTHER_SURGERY_KIDNEY
55.39.00	Sonstige lokale Exzision oder Destruktion von Läsion oder Gewebe an der Niere, n.n.bez.	OTHER_SURGERY_KIDNEY
55.39.22	Sonstige lokale Exzision oder Destruktion von Läsion oder Gewebe an der Niere, Destruktion, offen chirurgisch	OTHER_SURGERY_KIDNEY
55.39.23	Sonstige lokale Exzision oder Destruktion von Läsion oder Gewebe an der Niere, Destruktion, laparoskopisch	OTHER_SURGERY_KIDNEY
55.39.29	Sonstige lokale Exzision oder Destruktion von Läsion oder Gewebe an der Niere, Destruktion, sonstiger Zugang	OTHER_SURGERY_KIDNEY
55.39.99	Sonstige lokale Exzision oder Destruktion von Läsion oder Gewebe an der Niere, sonstige	OTHER_SURGERY_KIDNEY
55.4	Partielle Nephrektomie	PARTIELLE_NEPHREKTOMIE
55.51.00	Nephroureterektomie, n.n.bez.	TOTALE_NEPHREKTOMIE
55.51.01	Nephroureterektomie, ausser zur Transplantation	TOTALE_NEPHREKTOMIE
55.51.99	Nephroureterektomie, sonstige	TOTALE_NEPHREKTOMIE
55.52	Nephrektomie einer belassenen Niere	TOTALE_NEPHREKTOMIE
55.54	Beidseitige Nephrektomie	TOTALE_NEPHREKTOMIE

Table 3: Regression analysis of the association between the year of treatment and surgical method

	Odds ratio	95% Confidence interval		*p value*
Univariable				
Year of Treatment	1.09	1.08	1.11	< 0.001
Multivariable				
Year of Treatment	1.09	1.08	1.11	< 0.001
Age (45-59)	0.87	0.65	1.17	0.36
Age (50-54)	0.83	0.64	1.08	0.16
Age (55-59)	0.83	0.64	1.07	0.15
Age (60-64)	0.66	0.51	0.84	< 0.001
Age (65-69)	0.77	0.6	0.97	0.03
Age (70-74)	0.58	0.46	0.74	< 0.001
Age (75-79)	0.53	0.41	0.68	< 0.001
Age (80-84)	0.3	0.24	0.4	< 0.001
Age (80+)	0.18	0.11	0.3	< 0.001
Gender (male)	1.08	0.97	1.22	0.14

Multivariable regression analysis of the year of treatment adjusted for age and gender. Reference Age = (0-44)

Table 4: Univariable and multivariable logistic regression of the association between tumor stage and surgical method

	Odds ratio	95% Confidence interval		*p value*
Univariable				
pt2	0.12	0.1	1.15	< 0.001
pt3	0.1	0.08	0.12	< 0.001
pt4	0.2	0.01	0.09	< 0.001
ptX	0.43	0.26	0.73	< 0.002
Multivariable				
pt2	0.12	0.1	0.15	< 0.001
pt3	0.1	0.09	0.12	< 0.001
pt4	0.02	0.01	0.09	< 0.001
ptX	0.47	0.27	0.8	0.006
Age (45 - 49)	0.77	0.56	1.07	0.12
Age (50 - 54)	0.87	0.65	1.18	0.38
Age (55 - 59)	0.82	0.62	1.08	0.16
Age (60 - 64)	0.63	0.48	0.82	< 0.001
Age (65 - 69)	0.77	0.59	1	0.05
Age (70 -74)	0.6	0.46	0.78	< 0.001
Age (75 - 79)	0.55	0.42	0.72	< 0.001
Age (80 - 84)	0.36	0.26	0.5	< 0.001
Age (85+)	0.21	0.12	0.35	< 0.001
Gender (male)	1.08	0.96	1.22	0.21

Odds ratios (OR) and 95% confidence intervals (CI) for surgical method (PN) according to tumor stage, adjusted for age and gender in the multivariable model. Reference category for tumor stage: pT1.

Table 5: Regression analysis of the association between region and surgical method

	Odds ratio	95% Confidence interval		*p value*
Multivariable				
Midlands	1.16	1.01	1.34	0.04
Northwestern Switzerland	1.1	0.9	1.35	0.34
Eastern Switzerland	1.02	0.88	1.18	0.8
Ticino	0.36	0.29	0.45	< 0.001
Central Switzerland	1.7	1.37	2.12	< 0.001
Zurich	1.13	0.99	1.29	0.07
Lake Geneva Region	0.93	0.79	1.08	0.32
Age (45 - 49)	0.77	0.56	1.07	0.12
Age (50 - 54)	0.88	0.66	1.18	0.39
Age (55 - 59)	0.82	0.62	1.09	0.17
Age (60 - 64)	0.63	0.48	0.82	< 0.001
Age (65 - 69)	0.77	0.59	1	0.05
Age (70 -74)	0.6	0.46	0.78	< 0.001
Age (75 - 79)	0.55	0.42	0.72	< 0.001
Age (80 - 84)	0.36	0.26	0.49	< 0.001
Age (85+)	0.21	0.12	0.345	< 0.001
pt2	0.12	0.09	0.149	< 0.001
pt3	0.1	0.095	0.12	< 0.001
pt4	0.02	0.004	0.07	< 0.001
ptX	0.47	0.27	0.79	0.01

Odds ratios (OR) adjusted for age and tumor stage.

Table 6: Regression analysis of the association between Gender and Treatment

	Odds ratio	95% Confidence interval		*p value*
Univariable				
Gender (male)	1.15	1.03	1.28	0.01
Multivariable				
Gender (male)	1.10	0.97	1.24	0.15
Age (45-59)	0.77	0.55	1.07	0.12
Age (50-54)	0.88	0.65	1.18	0.39
Age (55-59)	0.82	0.62	1.09	0.17
Age (60-64)	0.62	0.47	0.81	0.00
Age (65-69)	0.76	0.58	0.99	0.04
Age (70-74)	0.59	0.45	0.77	< 0.001
Age (75-79)	0.54	0.41	0.71	< 0.001
Age (80-84)	0.37	0.27	0.51	< 0.001
Age (80+)	0.20	0.12	0.34	< 0.001
Midlands	1.21	1.00	1.47	0.05
Northwestern Switzerland	1.17	0.92	1.49	0.19
Eastern Switzerland	1.09	0.90	1.32	0.39
Ticino	0.42	0.33	0.54	< 0.001
Central Switzerland	1.74	1.35	2.25	< 0.001
Zurich	1.18	0.98	1.41	0.08
pt2	0.11	0.09	0.14	< 0.001
pt3	0.10	0.08	0.12	< 0.001
pt4	0.02	0.01	0.09	< 0.001
ptX	0.58	0.33	1.01	0.05

Multivariable regression analysis of gender adjusted for age, region and T-stage

Table 7 : Odds ratio (OR) and 95% confidence intervals (CI) for PN by region stratified by gender

	Odds ratio	95% Confidence interval		*p value*
Lake Geneva region (♀)	1.05	0.81	1.34	0.72
Midlands (♀)	1.09	0.85	1.38	0.5
Northwestern Switzerland (♀)	0.9	0.64	1.26	0.55
Eastern Switzerland (♀)	1.2	0.95	1.52	0.13
Ticino (♀)	0.31	0.21	0.46	< 0.001
Central Switzerland (♀)	1.26	0.89	1.77	0.19
Zurich (♀)	1.16	0.93	1.43	0.19
Lake Geneva region (♂)	1.01	0.86	1.19	0.89
Midlands (♂)	1.17	1.01	1.36	0.034
Northwestern Switzerland (♂)	1.07	0.87	1.32	0.5
Eastern Switzerland (♂)	0.94	0.81	1.09	0.39
Ticino (♂)	0.45	0.36	0.56	< 0.001
Central Switzerland (♂)	1.36	1.09	1.71	0.007
Zurich (♂)	1.12	0.98	1.29	0.1

Table 8: Risk factor analyses

Risk Factor	Categories / Levels	Effect on PN Likelihood	Statistics / Notes
Age	0–44, 45–64, 65–69, 70–84, 85+	Younger patients more likely to receive PN; probability decreases with age	PN 0–44: 54.5%; PN 85+: 0.2%; age correlates with T-stage (pT1: 71% in 0–44 vs 45% in 85+)
T-stage	pT1, pT2, pT3, pT4	Higher T-stage → lower PN likelihood	Univariable OR (ref pT1): pT2 0.12, pT3 0.10, pT4 0.02; all $p < 0.001$; effect persists after adjustment for age & gender
Setting	Curative vs Palliative	PN more common in curative settings	Curative: PN 47.7%; Palliative: PN 12.2%
Region	Central, Zurich, Lake Geneva, Midlands, Northwestern, Eastern, Ticino	Regional differences affect PN likelihood	Multivariable ORs (adjusted for age & T-stage): Ticino 0.36, Central 1.7; reference = all other regions combined; regional trends vary over time
Gender	Male vs Female	Slight male preference in univariable analysis; not significant after adjustment	Univariable OR: 1.15 (p=0.014); adjusted OR: 1.10 (p=0.15); male vs. female pT1 (64.5% vs 61.7%)
Year of treatment	2008–2020	Later years → higher likelihood of PN	Univariable OR per year (pT1): 1.09 (95% CI 1.075–1.11, $p < 0.001$); effect persists after adjustment for age & gender
Surgical approach	Open vs Laparoscopic	Increasing use of laparoscopic PN over time	Laparoscopic PN: 11.7%, Open PN: 21.4%; lap PN rose from 21.1% in 2011 to 45.2% in 2018

Table 9: Selection of Patients for Analysis according to STROBE - NACR Dataset (2008-2020)

Step	Patients	Notes / Exclusions
Total patients in NACR database	10'810	All Patients with kidney tumors who underwent therapy
Excluded: Missing T stage or treatment type	3'930	Ensure complete data for main analysis
Excluded: Rare/unconventional treatment (<3 cases) or percutaneous ablation	84	Focus on standard surgical methods
Patients included in final analysis	6'565	60.7% of total cohort; used for PN vs RN analysis

Table 10: Selection of Patients for Analysis according to STROBE - FSO Dataset (2008-2018)

Step	Patients	Notes / Exclusions
Total nephrectomy procedures included	10'700	All patients included, no exclusions applied