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Minimally invasive and nephron-sparing surgery for renal cell carcinoma: a nationwide analysis of 228,185 nephrectomies in Germany, 2011–2024

Julian Risch

Julian.Risch@uksh.de

University Hospital Schleswig-Holstein

Jakob Kohler

University Hospital Schleswig-Holstein

Leonhard Buck

University Hospital Schleswig-Holstein

Oscar Weische

University Hospital Schleswig-Holstein

Marie-Luise Weiss

University Hospital Schleswig-Holstein

Thea Henningsen

University Hospital Schleswig-Holstein

Neele Heckmann

University Hospital Schleswig-Holstein

Patricia Schließer

University Hospital Schleswig-Holstein

Benedikt-Johannes Becker

University Hospital Schleswig-Holstein

Jakob Voran

University Hospital Schleswig-Holstein

Jonas Jarczyk

University Hospital Schleswig-Holstein

Sebastian Berg

University Hospital Schleswig-Holstein

Philipp Nuhn

University Hospital Schleswig-Holstein

Severin Rodler

University Hospital Schleswig-Holstein

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Minimally invasive and nephron-sparing surgery for renal cell carcinoma: a nationwide analysis of 228,185 nephrectomies in Germany, 2011–2024

Julian Risch[1,†,*], Jakob Kohler[1,†], Leonhard Buck[1,2], Oscar Weische[1], Marie-Luise Weiss[1], Thea Henningsen[1], Neele Heckmann[1], Patricia Schließer[1], Benedikt-Johannes Becker[1], Jakob Voran[1], Jonas Jarczyk[1], Sebastian Berg[1,2], Philipp Nuhn[1,2], Severin Rodler[1,2]

[1] Department of Urology, University Hospital Schleswig-Holstein, Campus Kiel, Kiel, Germany
[2] Kurt-Semm Center for Laparoscopic and Robotic Surgery, University Hospital Schleswig-Holstein, Kiel, Germany

[†] Julian Risch and Jakob Kohler contributed equally to this work and share first authorship.

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*** Corresponding author**
Dr. Julian Risch, M.D., Department of Urology, University Hospital Schleswig-Holstein, Campus Kiel
Arnold-Heller-Strasse 3, 24105 Kiel, Germany
Email: Julian.Risch@uksh.de · Phone: +49 431 500 24820
ORCID: 0009-0004-7984-0826

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Minimally invasive and nephron-sparing surgery for renal cell carcinoma: a nationwide analysis of 228,185 nephrectomies in Germany, 2011–2024

Abstract

Purpose Nephron-sparing and minimally invasive surgery are recommended for localised renal cell carcinoma, but the supporting evidence comes largely from expert centres. We examined whether their advantages hold in routine care and whether access is equitable.

Methods We analysed all 228,185 adult nephrectomies performed for renal malignancy in the German hospital discharge census between 2011 and 2024. Outcomes were in-hospital mortality, a composite of major adverse cardiac and cerebrovascular events extended for renal surgery (MACCE-RN), acute kidney injury, dialysis and length of stay. Access was compared by mixed-effects logistic regression with random hospital intercepts, procedure type by inverse probability of treatment weighting.

Results The minimally invasive share rose from 19.7% to 59.4%, robot assistance from 9.7% to 79.4% of those procedures, and partial nephrectomy overtook radical nephrectomy in 2017, reaching 62.5% by 2024. Minimally invasive access showed lower adjusted odds of death (odds ratio 0.49, 95% confidence interval 0.42–0.56), MACCE-RN (0.56, 0.52–0.60) and acute kidney injury (0.57, 0.54–0.60), and a 26% shorter stay, with no difference in dialysis. Partial nephrectomy showed lower odds of death (0.61) and dialysis (0.41), without broadening to higher-risk patients. Uptake depended on the treating hospital: minimally invasive surgery had ever been performed in 17.9% of the smallest centres and 95.9% of the largest.

Conclusion Both approaches became predominant and reproduced in routine care the advantages reported from expert centres, but their adoption depended on hospital volume rather than on patient characteristics. Administrative data lack tumour stage and follow-up beyond discharge.

1. Introduction

Kidney cancer accounted for an estimated 434,000 new cases and 155,700 deaths worldwide in 2022 [1]. Cross-sectional imaging has changed how the disease presents: the rise in incidence is driven almost entirely by small, incidentally detected renal masses in older patients [2]. Surgery remains the only established curative treatment [3], so both the safety of nephrectomy and the amount of kidney it costs matter.

Two developments have reshaped this operation. The first is nephron-sparing surgery. Radical nephrectomy is an independent risk factor for new-onset chronic kidney disease [4] and the only randomised comparison of the two operations, EORTC 30904, confirmed that partial nephrectomy reduces moderate renal dysfunction [5]. The The European Association of Urology recommends partial nephrectomy for all T1 tumours whenever technically feasible, and advises against minimally invasive radical nephrectomy where it is [3]. The second is the spread of minimally invasive, increasingly robot-assisted access, for which randomised evidence is confined to small trials of partial nephrectomy [6, 7].

Both recommendations rest largely on series from high-volume academic centres, and EORTC 30904 reported lower overall survival after partial nephrectomy, a contested result from a trial closed prematurely for poor accrual [8]. Whether these recommendations reached everyday practice, whether the advantages seen in expert hands persist nationally, and whether access is equitable cannot be answered from institutional series.

We therefore examined every nephrectomy for renal malignancy performed in Germany over 14 yr, using the nationwide hospital discharge census. We tracked the shift from open to minimally invasive access and from radical to nephron-sparing partial nephrectomy. We then compared perioperative outcomes between minimally invasive and open access and between partial and radical nephrectomy with risk adjustment. Finally, we determined how far uptake depended on the treating centre rather than on the patient.

2. Patients and methods

Data source and ethics. We analysed the German nationwide diagnosis-related group (DRG) hospital discharge statistics (§21 KHEntgG) for 2011–2024, a mandatory full census of all inpatient episodes in German acute-care hospitals held by the Research Data Centre of the Federal Statistical Office (FDZ/DESTATIS). Analyses ran on anonymised microdata inside the secure FDZ environment, and only disclosure-checked aggregates were released. The study was approved by the Ethics Committee of Christian-Albrechts-University Kiel (D 511/26). Informed consent was not required. Reporting follows the RECORD statement [9]. The completed checklist is provided in **Online Resource 1**.

Cohort. We included all episodes with a nephrectomy code (Operationen- und Prozedurenschlüssel [OPS] 5-553 or 5-554) and a diagnosis of renal malignancy (ICD-10 C64–C66) in adults (≥18 yr), excluding living-donor and graft nephrectomies (5-554.7/.8/.9). Procedures were classified as partial nephrectomy (PN, 5-553), radical or simple nephrectomy (5-554.4/.a), or nephroureterectomy (5-554.5/.6/.b), the last excluded from the nephron-sparing comparison (**Online Resource 2**).

Exposures. Surgical approach was derived from the terminal digit of the index OPS code, whose structure is identical across all annual catalogues (digits 0 to 2 open, 3 laparoscopic or retroperitoneoscopic). A terminal digit of 3 defined minimally invasive surgery (MIS) and code 5-987 identified robotic assistance. Episodes without a codable digit were excluded from approach comparisons. Annual centre volume was the number of nephrectomies per institution and year, categorised as 1–5, 6–15, 16–30, and >30 procedures/yr.

Covariates. Age, sex, calendar year, and annual centre volume were taken from the discharge record. Comorbidity was ascertained from secondary ICD-10 diagnoses. Risk adjustment used the van Walraven point score derived from the Elixhauser comorbidity measures [10]. The Charlson comorbidity index [11] was computed for the case-mix drift analyses only.

Outcomes. The main outcomes were in-hospital mortality, major adverse cardiac and cerebrovascular events (MACCE-RN), acute kidney injury, dialysis, and length of stay (LOS). MACCE-RN was defined as death, myocardial infarction, stroke, intracranial haemorrhage, cardiopulmonary resuscitation, or reoperation. Acute kidney injury and dialysis were kept outside the composite, because renal function is the outcome of central interest in nephron-sparing surgery. All outcomes were identified from ICD-10 and OPS codes and refer to the index hospital stay. Further perioperative complications were recorded and analysed identically.

Statistical analysis. Continuous variables are reported as median [interquartile range], proportions with 95% Wilson confidence intervals. Adjusted effects of approach were estimated by mixed-effects logistic regression with a random hospital intercept, adjusted for procedure type, age category, sex, van Walraven score, log annual centre volume, and calendar year. LOS was modelled log-linearly and is reported as a geometric mean ratio. PN was compared with radical nephrectomy by inverse probability of treatment weighting, using stabilised weights truncated at the 1st and 99th centiles in quasibinomial models clustered on hospital [12]. Propensity score matching within centre-volume tertiles served as a sensitivity analysis [13]. The learning curve was modelled as years since a centre's first robotic case, case-mix drift as covariate-by-year interactions. Analyses were complete-case and two-sided at $p < 0.05$. Cells with fewer than five cases were suppressed per FDZ rules. R version 4.3 was used (lme4, survey, MatchIt).

Use of generative artificial intelligence. Claude (Anthropic) was used to assist with drafting and language editing of the manuscript, with the preparation of tables and figure legends, and with literature searching and verification of references. It was not used to generate, process or analyse study data. All statistical analyses were performed in R by the authors, who reviewed and edited the entire manuscript and take full responsibility for its content.

3. Results

3.1. Cohort and baseline characteristics

Of 335,124 hospital episodes carrying a nephrectomy code, 229,944 also carried a diagnosis of renal malignancy. After restriction to adults and exclusion of 196 donor or graft procedures, 228,185 nephrectomies formed the analytic cohort (**Online Resource 2**). Partial nephrectomy accounted for 96,828 procedures (42.4%), radical or simple nephrectomy for 92,896 (40.7%), and nephroureterectomy or procedures not further specified for 38,461 (16.9%). Surgical approach was codable in 227,255 episodes, of which 78,976 (34.7%) were minimally invasive, including 37,683 robot-assisted, and 148,279 were open. The annual case load remained stable at approximately 16,000 procedures throughout the study period.

Patients treated minimally invasively were younger (median 68 yr [IQR 59–76] vs 69 yr [60–76]) and carried a lower comorbidity burden (van Walraven score 4 [4–9] vs 7 [4–14]), with lower rates of chronic kidney disease (13.6% vs 17.2%), heart failure (2.0% vs 2.6%) and anaemia (1.5% vs 2.6%). The difference was most pronounced for inferior vena cava thrombus (0.1% vs 1.7%). Full baseline data are given in **Table 1**, with all recorded comorbidities in **Online Resources 3 and 4** and motivate the risk-adjusted analyses that follow.

3.2. Two parallel shifts in surgical practice

Open nephrectomy fell from 12,937 procedures in 2011 to 6,746 in 2024, robot-assisted procedures rose from 309 to 7,878 and laparoscopic procedures declined from 2,893 to 2,047. The minimally invasive share therefore rose from 19.7% to 59.4% and robotics grew from 9.7% to 79.4% of all minimally invasive cases (**Fig. 1a**). In parallel, radical nephrectomies fell from 8,554 to 5,238, the partial nephrectomy share of parenchyma-directed procedures rose from 36.9% to 62.5%, and partial overtook radical nephrectomy in 2017 (**Fig. 1b**). Adoption was strongly volume-dependent, rising from 17.9% of centres treating 1–5 cases/yr to 95.9% of those exceeding 30, the largest centres also being the earliest adopters (median year of first minimally invasive case 2017) (**Fig. 1c**). With increasing institutional robotic experience, crude in-hospital mortality fell from 0.43% in the first year

to 0.19% beyond 5 yr and acute kidney injury from 4.8% to 3.8% (**Fig. 1d**). Within-hospital penetration and the shift in patient selection over time are shown in **Online Resources 5 and 6**.

3.3. Minimally invasive versus open nephrectomy

Crude morbidity was lower after minimally invasive surgery for every complication recorded (**Table 2**), including in-hospital death (0.5% vs 1.7%), MACCE-RN (2.3% vs 5.5%), acute kidney injury (5.5% vs 7.8%), dialysis (1.7% vs 3.1%) and transfusion (7.6% vs 21.3%) (**Fig. 2a and Fig. 2d**). After risk adjustment the advantage persisted for in-hospital death (OR 0.49, 95% CI 0.42–0.56), MACCE-RN (0.56, 0.52–0.60), acute kidney injury (0.57, 0.54–0.60), transfusion (0.35, 0.33–0.36), intensive care admission (0.43, 0.41–0.45) and venous thromboembolism (0.28, 0.26–0.31), all $p < 0.001$ (**Fig. 2b**). Dialysis was the only main outcome without a significant difference after adjustment (OR 0.98, 0.90–1.06, $p = 0.563$). Median length of stay was 7 d [5–9] versus 10 d [8–13], an adjusted geometric mean ratio of 0.74 (0.73–0.74, $p < 0.001$) or a 26% shorter stay (**Fig. 2c**). Remaining outcomes and learning-curve rates are given in **Online Resources 7 and 8** and the length-of-stay model in **Online Resource 9**.

3.4. Nephron-sparing versus radical nephrectomy

Crude event rates were lower after partial than after radical nephrectomy for death (0.5% vs 1.9%), MACCE-RN (2.5% vs 5.6%), acute kidney injury (5.1% vs 8.0%) and dialysis (1.0% vs 3.9%) (**Fig. 3a**). After inverse probability of treatment weighting, partial nephrectomy remained associated with lower odds of death (OR 0.61, 0.55–0.68), dialysis (0.41, 0.36–0.46), MACCE-RN (0.76, 0.72–0.81), acute kidney injury (0.83, 0.76–0.90), transfusion (0.76, 0.72–0.80) and reoperation (0.70, 0.64–0.76), all $p < 0.001$, whereas pneumonia showed no difference (OR 1.07, 1.00–1.15, $p = 0.056$) (**Fig. 3b**). Findings were consistent in propensity-matched analyses within volume tertiles (**Online Resource 10**). Partial nephrectomy utilisation rose in every volume stratum, but the gradient widened, reaching 65.6% by 2024 in centres exceeding 30 cases/yr versus 30.0% in those treating 1–5 (**Fig. 3c**). Covariate-by-year interaction odds ratios were below unity for anaemia (0.95), chronic kidney disease (0.98), heart failure (0.98) and metastatic disease (0.99), all $p < 0.05$, indicating that partial nephrectomy was not preferentially extended to higher-risk patients over time (**Fig. 3d and Online Resource 11**).

4. Discussion

Renal cancer surgery underwent two simultaneous transformations, with minimally invasive access tripling and becoming predominantly robotic while partial nephrectomy overtook radical nephrectomy in 2017. The

perioperative advantage reported by expert centres held nationwide after risk adjustment. Nephron preservation conferred an independent advantage, largest for dialysis. Access to both operations was determined by the volume of the treating hospital and for nephron-sparing surgery that disparity widened rather than closed. Finally, partial nephrectomy was not extended to higher-risk patients as it spread.

4.1. From open to minimally invasive and from radical to partial

Open surgery fell by almost half while robotic procedures rose 25-fold and laparoscopy declined in absolute terms as well, so robotics grew at the expense of both open surgery and, to a lesser extent, laparoscopy. The same substitution has been described in United States registry data [14]. Nephron-sparing surgery crossed the halfway mark in 2017, two years after the first German S3 guideline recommended it for all cT1 tumours at the highest grade [15]. That guideline codified a shift already under way rather than initiating it, because the partial share had reached 36.9% in 2011, against 29% of T1 disease in England in 2010 [16] and 35.3% of nephrectomies in the United States in 2009 to 2011 [17]. On nephron preservation Germany was therefore an early adopter. On minimally invasive access it was not. Minimally invasive surgery already accounted for 75% of oncological nephrectomies in the United Kingdom by 2017 [18] and robot-assisted partial nephrectomy had become the commonest approach to cT1 disease in the United States by 2019 [19], whereas the German minimally invasive share reached 59.4% only in 2024. The same 2015 guideline named open surgery the standard for nephron-sparing resection and endorsed a minimally invasive approach only for surgeons with sufficient experience [15], which may explain why the country led on one shift and lagged on the other. An independent analysis restricted to a single statutory health insurer found the same two shifts through 2021 [20].

4.2. The minimally invasive advantage holds nationwide

Halved odds of death (odds ratio 0.49) and a 26% shorter stay match what expert centres have reported and two observations argue against these estimates being pure artefact. The effects were graded in a mechanistically plausible way. Outcomes tied most directly to the incision, such as transfusion and venous thromboembolism, showed the largest reductions, whereas myocardial infarction and stroke showed the smallest. Dialysis showed no difference at all, which is what one would expect if the benefit arises from the incision rather than from the kidney. Acute kidney injury sits between the two, falling with minimally invasive access while dialysis did not. One explanation may be that postoperative acute kidney injury is driven partly by blood loss and intraoperative hypotension [21] and that minimally invasive access reduces both blood loss and transfusion [22], whereas dialysis reflects the amount of kidney removed, which the approach cannot change. Pneumoperitoneum itself

lowers renal perfusion during laparoscopy [23], so the net advantage suggests that reduced bleeding outweighs that transient effect. Such a gradient is difficult to generate by selection alone. Residual confounding nevertheless remains likely, because patients selected for minimally invasive surgery were healthier and rarely had caval tumour thrombus. The randomised evidence is thin: the one trial designed to compare perioperative complications reached a third of its recruitment target and found no difference [7] and the other randomised comparison was a feasibility study [6]. These odds ratios therefore describe the benefit under real-world selection, not the effect of the approach itself.

4.3. Nephron preservation and dialysis

Partial nephrectomy showed the same direction of effect across every outcome examined, lowering the odds of death (odds ratio 0.61) and, most of all, of dialysis, the endpoint that most directly reflects preserved parenchyma. This is consistent with the established association between radical nephrectomy and new-onset chronic kidney disease [4] and with the finding of the randomised EORTC 30904 trial that nephron-sparing surgery reduces moderate renal dysfunction [5]. That trial found no difference in kidney failure, but its inclusion criteria of a small tumour and a normal contralateral kidney excluded the patients for whom nephron preservation matters most and it measured chronic function rather than dialysis during the index admission. This is also the point at which the randomised and the observational evidence continue to diverge, since EORTC 30904 also reported lower overall survival after partial nephrectomy [8], a finding that remains difficult to reconcile with the observational literature, in which partial nephrectomy is generally associated with lower all-cause mortality [24], although series adjusted for pathological as well as preoperative features show no difference in cancer-specific outcomes, so the survival gap is widely ascribed to selection [25, 26]. Mean renal function in both trial arms also stayed above the threshold at which chronic kidney disease begins to drive mortality, leaving little survival difference to detect [26]. Our data cannot contribute to that question, because they end at discharge. What they do show is that nephron preservation carried no penalty during the index admission for death, acute kidney injury or reoperation. The specific objection to it has always been urinary fistula and haemorrhage, which EORTC 30904 recorded almost exclusively in the nephron-sparing arm [27] and which our comparison did not examine separately.

4.4. Access is gated by hospital volume

The most consequential finding is the inequality of access. Minimally invasive surgery had ever been performed in 95.9% of the largest centres but in only 17.9% of those operating one to five cases annually and the gap in

nephron-sparing surgery widened rather than closed. Crude mortality and acute kidney injury both fell as institutional robotic experience accumulated, so where a patient is treated affects not only which operation is offered but how safely it is delivered. Volume-outcome relationships in nephrectomy are established for perioperative morbidity [28] and for mortality within the first year after surgery, although not beyond it [29], which places that effect in the early period our data cover. Comparable inequities in access have been reported in the United States along socioeconomic and racial lines [14].]. That the German gradient is institutional rather than socioeconomic makes it no more acceptable, but it does make it more tractable, because referral pathways, structured proctoring and minimum-volume requirements change where patients are treated and by whom, whereas buying more robots does not. Germany is now implementing exactly that, since a hospital reform enacted in 2024 assigns every procedure to a defined service group carrying structural and minimum-volume requirements, urology among them [30], although the thresholds themselves have yet to be set. Our findings provide a baseline against which that reform can be judged.

4.5. Indications did not broaden

As partial nephrectomy spread, patients with anaemia, chronic kidney disease or heart failure became relatively less likely to receive it. The per-year effects are small and reach significance largely because of cohort size, but they compound: the annual interaction odds ratio of 0.95 for anaemia amounts to a halving of the association between anaemia and partial nephrectomy across the study period, with a decline of roughly one quarter for chronic kidney disease. One interpretation is that the expansion remained clinically appropriate. Another is that the drift went in the wrong direction for patients with limited renal reserve, who are least able to tolerate the loss of a whole kidney [4]. Our data cannot distinguish appropriate caution from missed opportunity. A single trend in administrative data is not a basis for changing practice, but it is a reason to ask whether referral is reaching these patients.

4.6. Limitations

Administrative data carry no tumour stage, size, histology or nephrometry score and no performance status, so confounding by indication cannot be excluded despite adjustment, weighting and matching. Outcomes end at discharge, leaving readmission, later mortality, cancer-specific survival and renal function unobserved, which matters most for the nephron-sparing comparison, where an analysis with 30-day follow-up found more reinterventions after partial nephrectomy [20]. Comorbidities and complications were identified from ICD-10 and OPS codes, so coding depth and reimbursement incentives may influence ascertainment. Surgical approach

was inferred from the terminal digit of the procedure code, so intraoperative conversions cannot be identified and are counted as minimally invasive and robot assistance was identified from an add-on code that may be recorded incompletely. The comparison of partial with radical nephrectomy was balanced on patient characteristics but not on surgical access and because partial resections were more often performed minimally invasively, the estimates for death, MACCE-RN and transfusion partly reflect the advantage of the approach rather than of nephron preservation. Dialysis is unaffected by this, since access showed no association with dialysis. Volume was measured per hospital rather than per surgeon and hospital identifiers denote sites rather than networks, so shared or split identifiers may distort the volume measure. Finally, odds ratios from the mixed-effects models are conditional on the hospital, whereas those from weighting are marginal, so the two sets of estimates should not be compared directly.

5. Conclusions

Minimally invasive access and nephron-sparing surgery both became predominant during the study period and delivered in unselected routine care the perioperative advantages described in expert series, nephron preservation most clearly for dialysis. What limits benefit is therefore no longer the technique but its distribution. Uptake depended mainly on the volume of the treating hospital and, to a lesser degree, on the comorbidity of the patient. Neither is a technological constraint, and outcomes improved with accumulated institutional experience rather than with the arrival of the equipment, so investment in devices alone is unlikely to close the gap. The hospital reform now under way in Germany acts on hospital volume but not on patient selection, and these figures provide a baseline against which it can be assessed.

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Figure legends

Fig. 1 Trends in surgery for renal cancer in Germany, 2011–2024. **(a)** Annual nephrectomies by surgical approach. **(b)** Partial versus radical share of parenchymal nephrectomies, with crossover in 2017. **(c)** Proportion of centres ever adopting minimally invasive surgery by mean annual volume, with the median year of the first minimally invasive case. **(d)** Crude in-hospital mortality and acute kidney injury by institutional robotic experience.

MIS = minimally invasive surgery. Volume bands in (c) refer to the mean annual number of nephrectomies for renal malignancy per centre across all years in which the centre was active, whereas the volume bands in Fig. 3c refer to the caseload of the respective calendar year. Nephroureterectomies for upper tract urothelial carcinoma are included in (a) but not in (b)

Fig. 2 Minimally invasive versus open nephrectomy. **(a)** Crude event rates with 95% Wilson confidence intervals. **(b)** Adjusted odds ratios from mixed-effects logistic regression with a random hospital intercept, adjusted for procedure type, age category, sex, van Walraven score, log annual centre volume and calendar year; estimates in magenta indicate $p < 0.05$ and the dashed line marks an odds ratio of 1. **(c)** Length of stay (median [interquartile range]) with the adjusted geometric mean ratio. **(d)** Renal-specific morbidity.

CI = confidence interval; GMR = geometric mean ratio; OR = odds ratio; MACCE-RN = major adverse cardiac and cerebrovascular events extended for renal surgery, comprising in-hospital death, myocardial infarction, stroke, intracranial haemorrhage, cardiopulmonary resuscitation or reoperation, each patient counted only once. Panels labelled MACCE refer to MACCE-RN.

Each outcome in (b) was modelled separately, so the estimates are not adjusted for one another. The geometric mean ratio in (c) was obtained from a log-linear model adjusted for age, sex and van Walraven score only. All outcomes refer to the index hospital stay

Fig. 3 Partial (nephron-sparing) versus radical nephrectomy. **(a)** Crude event rates with 95% Wilson confidence intervals. **(b)** Inverse-probability-of-treatment-weighted adjusted odds ratios, using stabilised weights truncated at the 1st and 99th centiles with models clustered on hospital; estimates in magenta indicate $p < 0.05$. **(c)** Partial nephrectomy utilisation over time by centre volume. **(d)** Covariate-by-year interaction odds ratios for partial-nephrectomy selection.

CI = confidence interval; OR = odds ratio; MACCE-RN = major adverse cardiac and cerebrovascular events extended for renal surgery, comprising in-hospital death, myocardial infarction, stroke, intracranial

haemorrhage, cardiopulmonary resuscitation or reoperation, each patient counted only once. Panels labelled MACCE refer to MACCE-RN.

Nephroureterectomies for upper tract urothelial carcinoma were excluded from this comparison

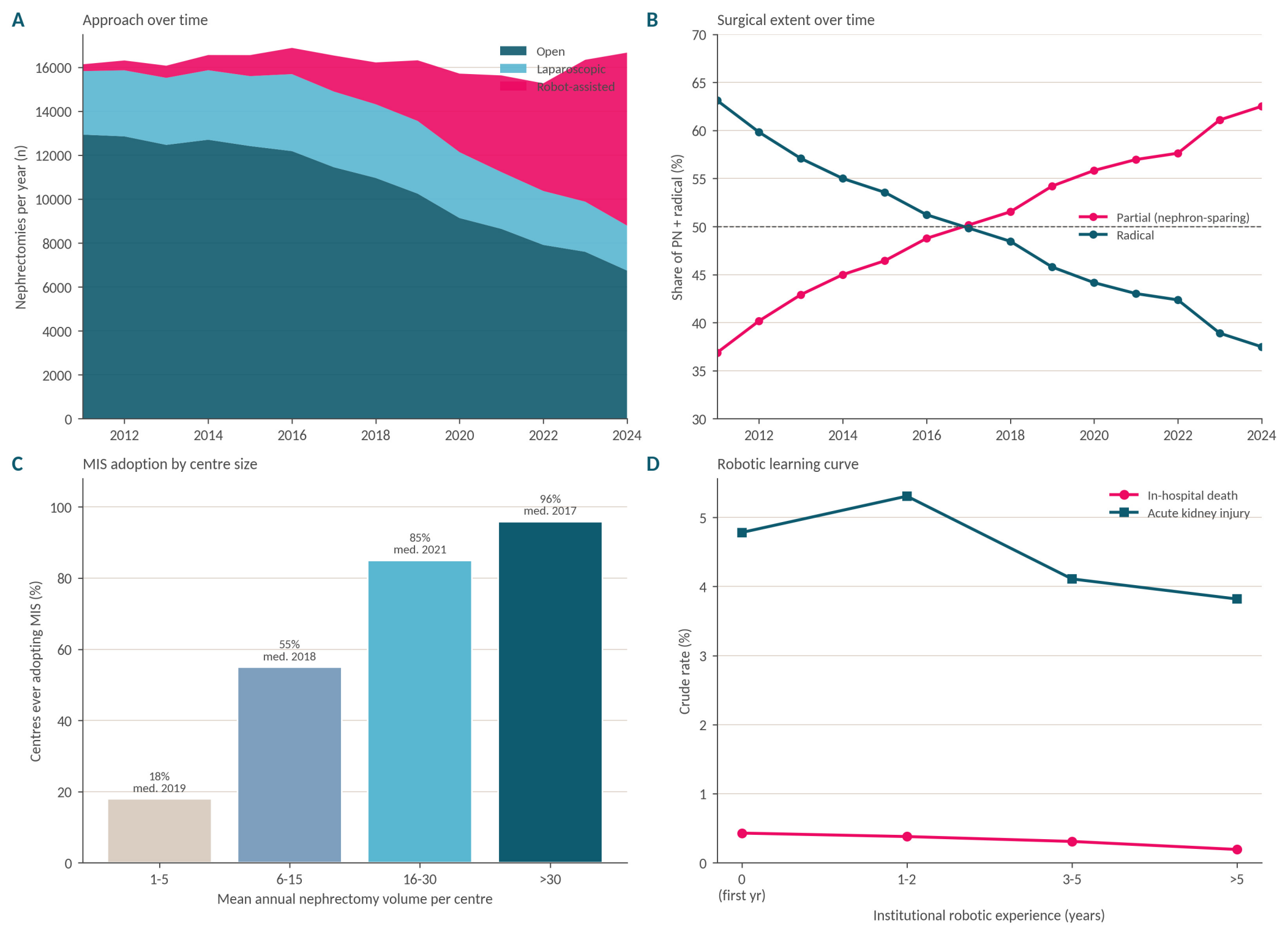
Table legends

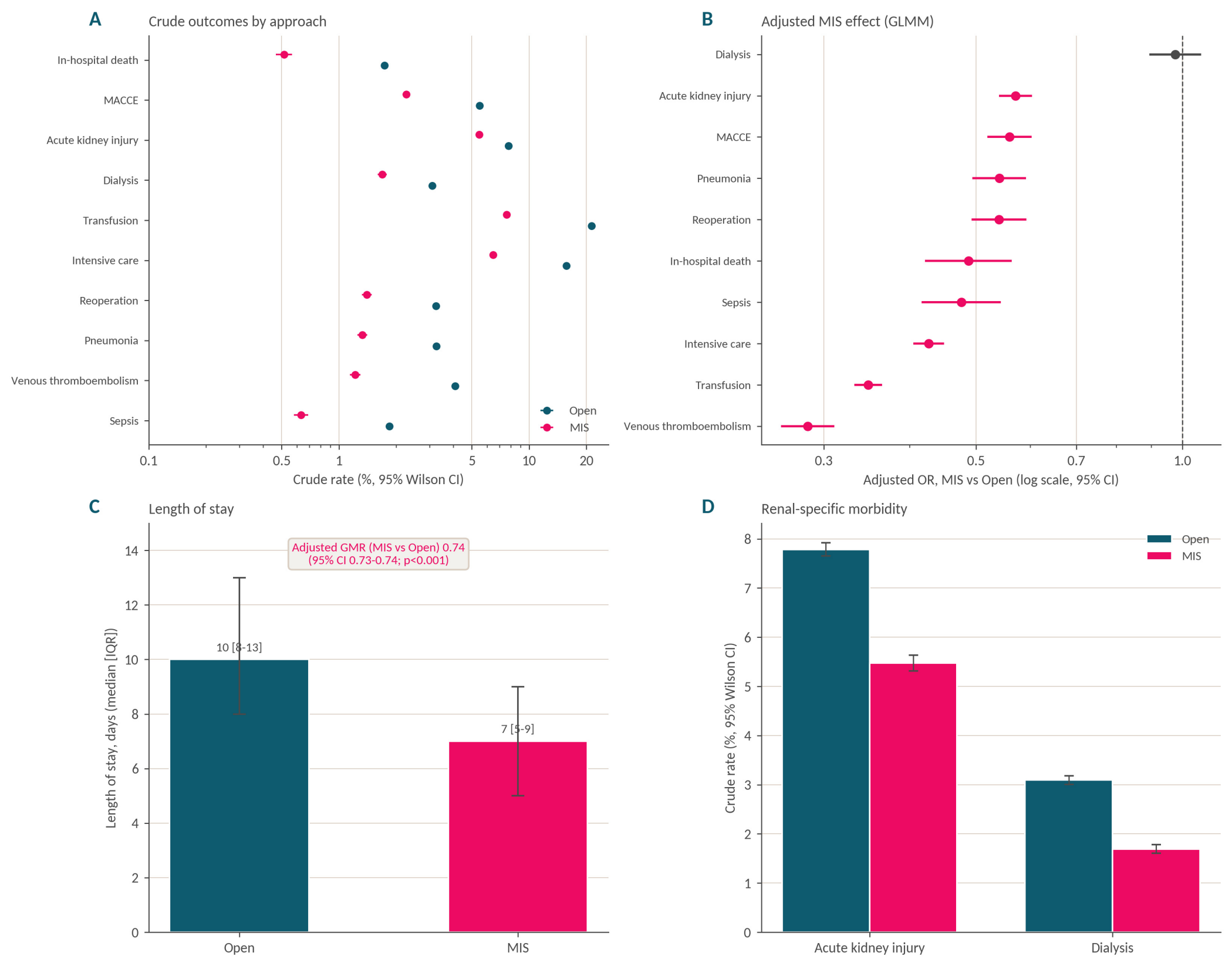
Table 1 Baseline characteristics of 227,255 nephrectomies for renal malignancy with a codable surgical approach, Germany 2011–2024. Continuous variables are median [interquartile range], categorical variables n (%)

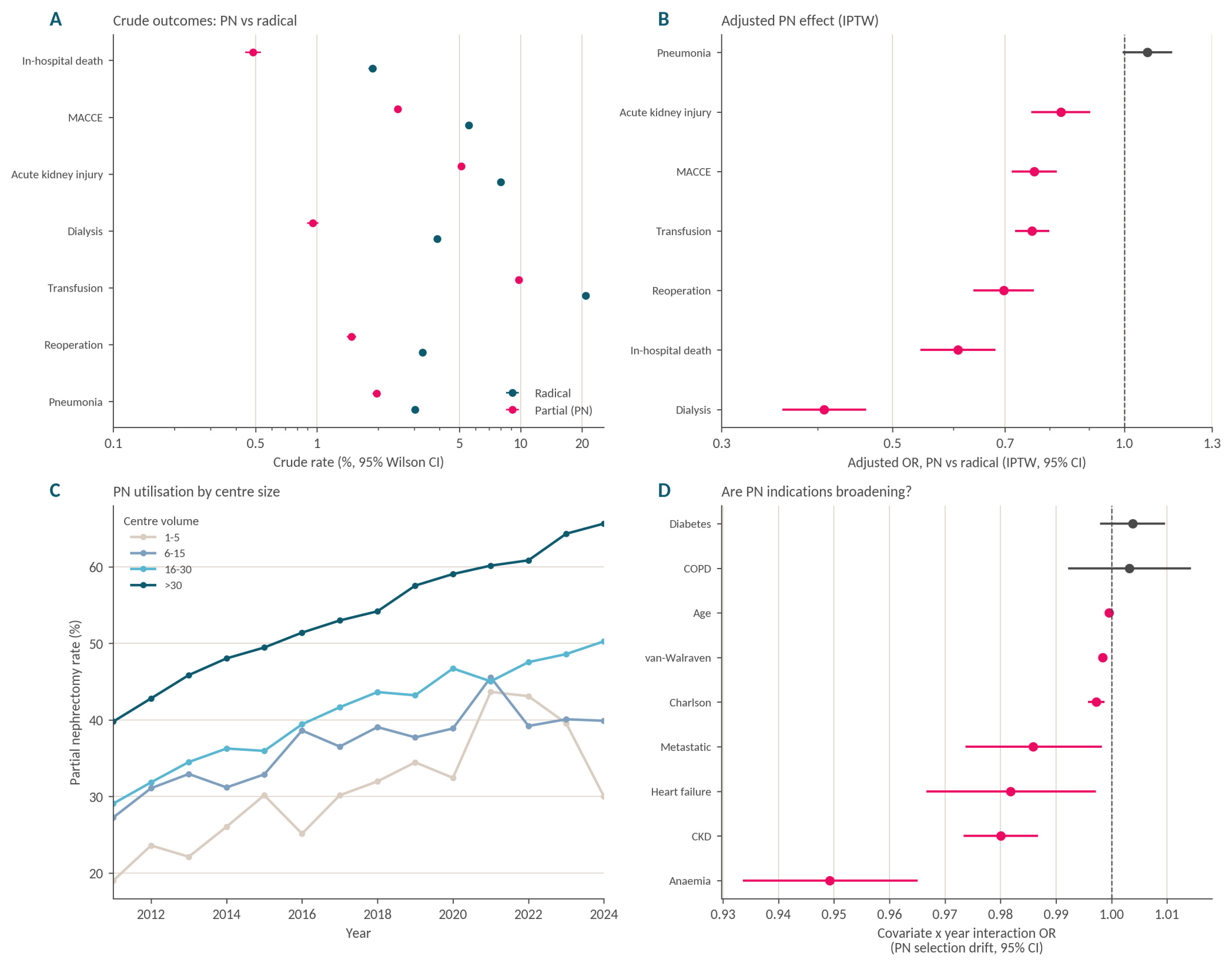
Table 2 Crude perioperative outcomes by surgical approach, shown as number of events and rate (% with 95% Wilson confidence interval)

Supplementary Information

Eleven online resources accompany this article. Online Resource 1: RECORD statement checklist. Online Resource 2: cohort flow. Online Resources 3 and 4: complete baseline characteristics by surgical approach and by procedure type. Online Resource 5: within-hospital minimally invasive penetration by centre-volume band. Online Resource 6: minimally invasive adoption drift. Online Resource 7: adjusted odds ratios across all 18 perioperative outcomes. Online Resource 8: crude outcome rates by institutional robotic experience. Online Resource 9: adjusted length-of-stay model. Online Resource 10: propensity-score-matched odds ratios within hospital-volume tertiles. Online Resource 11: partial nephrectomy selection drift.


A
Approach over time
Nephrectomies per year (n)
Open
Laparoscopic
Robot-assisted
B
Surgical extent over time
Share of PN + radical (%)
Partial (nephron-sparing)
Radical
C
MIS adoption by centre size
Centres ever adopting MIS (%)
18%
med. 2019
55%
med. 2018
85%
med. 2021
96%
med. 2017
1-5
6-15
16-30
>30
Mean annual nephrectomy volume per centre
D
Robotic learning curve
Crude rate (%)
In-hospital death
Acute kidney injury
0
(first yr)
1-2
3-5
>5
Institutional robotic experience (years)


A
Crude outcomes by approach
In-hospital death
MACCE
Acute kidney injury
Dialysis
Transfusion
Intensive care
Reoperation
Pneumonia
Venous thromboembolism
Sepsis
Open
MIS
0.1
0.5
1
5
10
20
Crude rate (%, 95% Wilson CI)
B
Adjusted MIS effect (GLMM)
Dialysis
Acute kidney injury
MACCE
Pneumonia
Reoperation
In-hospital death
Sepsis
Intensive care
Transfusion
Venous thromboembolism
0.3
0.5
0.7
1.0
Adjusted OR, MIS vs Open (log scale, 95% CI)
C
Length of stay
Adjusted GMR (MIS vs Open) 0.74
(95% CI 0.73-0.74; p<0.001)
Length of stay, days (median [IQR])
10 [8-13]
7 [5-9]
Open
MIS
D
Renal-specific morbidity
Open
MIS
Crude rate (%, 95% Wilson CI)
Acute kidney injury
Dialysis


A
Crude outcomes: PN vs radical
In-hospital death
MACCE
Acute kidney injury
Dialysis
Transfusion
Reoperation
Pneumonia
Radical
Partial (PN)
0.1
0.5
1
5
10
20
Crude rate (%, 95% Wilson CI)
B
Adjusted PN effect (IPTW)
Pneumonia
Acute kidney injury
MACCE
Transfusion
Reoperation
In-hospital death
Dialysis
0.3
0.5
0.7
1.0
1.3
Adjusted OR, PN vs radical (IPTW, 95% CI)
C
PN utilisation by centre size
Centre volume
1-5
6-15
16-30
>30
Partial nephrectomy rate (%)
20
30
40
50
60
2012
2014
2016
2018
2020
2022
2024
Year
D
Are PN indications broadening?
Diabetes
COPD
Age
van-Walraven
Charlson
Metastatic
Heart failure
CKD
Anaemia
0.93
0.94
0.95
0.96
0.97
0.98
0.99
1.00
1.01
Covariate x year interaction OR
(PN selection drift, 95% CI)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1MISnephronsparingnephrectomyJRS.docx
- Table2MISnephronsparingnephrectomyJRS.docx
- OnlineResourcesMISnephronsparingnephrectomyJRS.docx