NKCA
National Kidney Cancer Audit

NATCAN
National Cancer Audit Collaborating Centre

National Kidney Cancer Audit
State of the Nation Report: Appendix

An audit of care received by people diagnosed with kidney cancer between 1 January 2019 and 31 December 2023 in England and 1 January 2022 and 31 December 2024 in Wales. National time trends in kidney cancer diagnoses and treatments between 1 January 2019 and 30 September 2025 in England.

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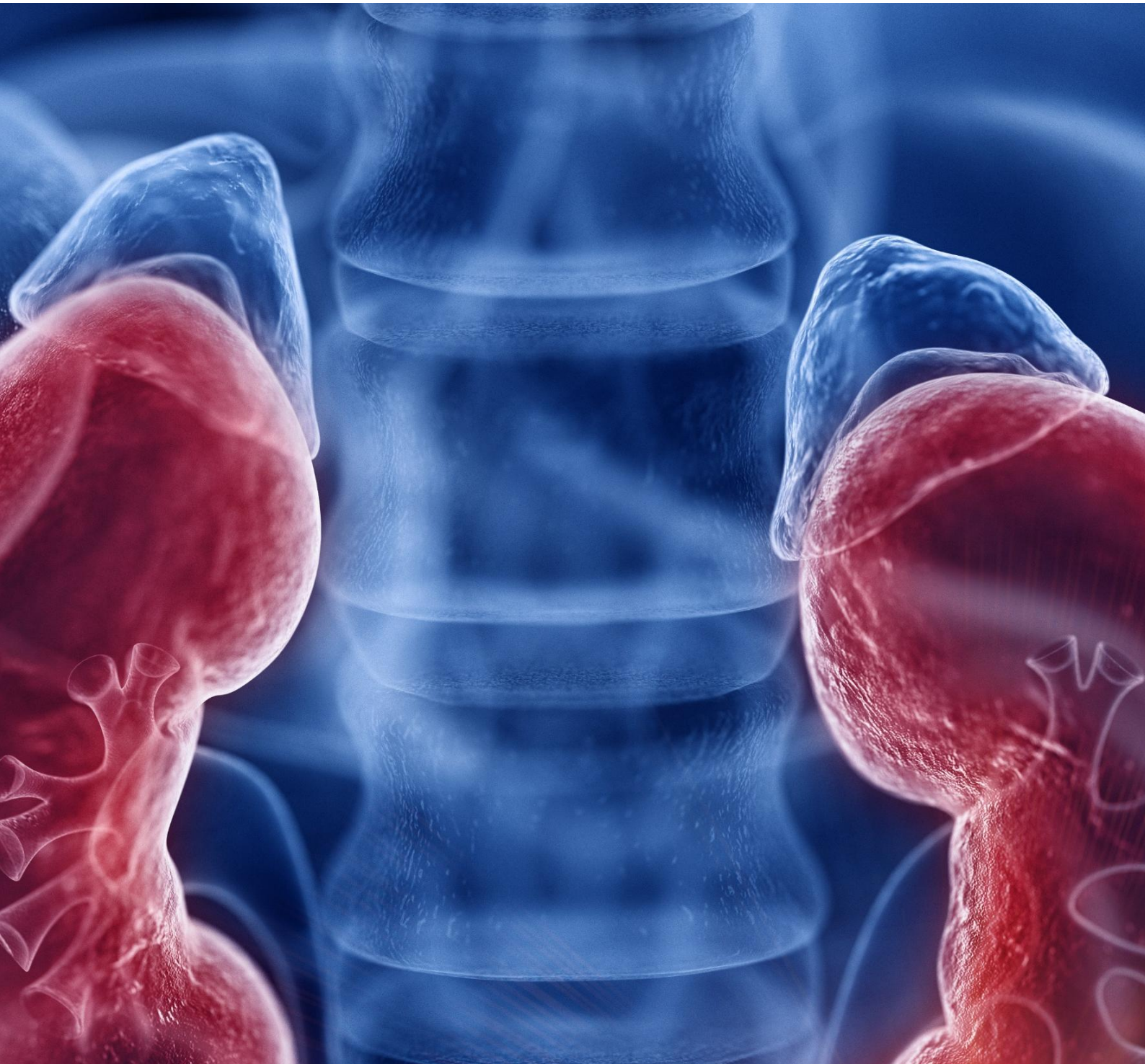

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Acknowledgements

The National Kidney Cancer Audit (NKCA) is part of the National Cancer Audit Collaborating Centre (NATCAN), a national centre of excellence to strengthen NHS cancer services by looking at treatments and outcomes for people diagnosed with cancer in multiple cancer types across England and Wales. NATCAN is commissioned by the Healthcare Quality Improvement Partnership (HQIP) on behalf of NHS England and the Welsh Government as part of the National Clinical Audit and Patient Outcomes Programme (NCAPOP).

Clinical leadership of the National Kidney Cancer Audit is provided by representatives from the British Association of Urological Surgeons (BAUS) and British Uro-Oncology Group (BUG). The audit is a collaboration between the Clinical Effectiveness Unit (CEU) at the Royal College of Surgeons of England (RCS), BAUS and BUG. We would like to thank British Association of Urological Surgeons and British Uro-Oncology Group for their continued professional guidance and for raising awareness amongst urological and uro-oncological colleagues.

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We would also like to thank all urologists, uro-oncologists along with their clinical and non-clinical teams at NHS Trusts in England and Local Health Boards in Wales who collected and submitted data for the audit. Your support is vital to enable the NKCA to evaluate the care that men receive following a diagnosis of kidney cancer in England and Wales and whether this care reflects national standards of care.

The NKCA compares NHS services in England and Wales and provides these results to underpin quality improvement activities. We are grateful to the National Cancer Registration and Analysis Service (NCRAS), which is part of the National Disease Registration Service, NHS England (NHSE) and the Wales Cancer Network, Public Health Wales for supporting routine cancer data submissions from Trusts and Local Health Boards and for supplying data for this report.

We would also like to thank all members of the NKCA Patient and Public Involvement (PPI) Forum, Action Kidney Cancer, and Kidney Cancer UK, for working with us to ensure that the voice of people who have had a kidney cancer diagnosis is central to the direction of the NKCA. A lay report summarising the key results will be developed in consultation with the NKCA PPI Forum and published in September 2026.

TNM (Tumour Node Metastasis) definitions

Table A1. TNM Stage adapted from UICC TNM 8 - UICC TNM staging for kidney cancer and EAU RCC Guidelines - TNM staging for kidney cancer	
T – Primary tumour	
T0	No Evidence of primary tumour
T1a	Tumour less than or equal to 4cm
T1b	Tumour more than 4cm but less than or equal to 7cm
T2a	Tumour more than 7cm but less than or equal to 10cm
T2b	Tumour more than 10cm but limited to the kidney
T3	Tumour extends into major veins or perinephric tissues but not into ipsilateral adrenal gland and not beyond Gerota fascia
T4	Tumour invades beyond Gerota fascia (including contiguous extension into the ipsilateral adrenal gland)
N- Regional Lymph Nodes	
N0	No regional lymph node metastasis
N1	Metastasis in regional lymph node(s)
M – Distant metastasis	
M0	No distant metastasis
M1	Distant metastasis

T3+ and/or 10cm+ and/or N1 M0 RCC	Tumour extends into major veins or perinephric tissues or invades beyond Gerota fascia and/or tumour more than 10cm in size and/or metastasis in regional lymph node(s) with no distant metastasis
T1b-3NXM0 RCC	Tumour is more than 4cm in size or tumour extends into major veins or perinephric tissues with no distant metastasis
T1aN0M0 RCC	Tumour is less than or equal to 4cm in size with no regional lymph node metastasis and no distant metastasis

Supplementary figures and tables

Table A2. Patient characteristics for people newly diagnosed with kidney cancer in England over the period of 1 January 2021 - 31 December 2023.								
Data variable	**England**							
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Time period covered	***1 Jan 2021 - 31 Dec 2023***		***2021***		***2022***		***2023***	
No. of people with new diagnosis of kidney cancer	30,795		9,923		10,205		10,667	
Age								
<45	1,524	5%	507	5%	497	5%	520	5%
45-54	3,497	11%	1,192	12%	1,178	12%	1,127	11%
55-64	6,895	22%	2,164	22%	2,262	22%	2,469	23%
65-74	8,947	29%	2,856	29%	2,984	29%	3,107	29%
75-84	7,272	24%	2,287	23%	2,427	24%	2,558	24%
>85	2,660	9%	917	9%	857	8%	886	8%
Total	30,795	100%	9,923	100%	10,205	100%	10,667	100%
Missing	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*
Gender (Self-stated gender at diagnosis)								
Male	19,825	64%	6,446	65%	6,548	64%	6,831	64%
Female	10,970	36%	3,477	35%	3,657	36%	3,836	36%
Total	30,795	100%	9,923	100%	10,205	100%	10,667	100%
Missing	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*
Performance status*								
0	8,612	59%	2,506	59%	2,823	60%	3,283	59%
1-2	4,961	34%	1,474	34%	1,606	34%	1,881	34%
≥3	956	7%	302	7%	289	6%	365	7%
Total	14,529	100%	4,282	100%	4,718	100%	5,529	100%
Missing	*16,266*	*(53%)*	*5,641*	*(57%)*	*5,487*	*(54%)*	*5,138*	*(48%)*
Number of co-morbidities (Charlson score)								
0	10,908	43%	3,538	42%	3,579	43%	3,791	43%
1	4,939	19%	1,653	20%	1,620	19%	1,666	19%
≥2	9,705	38%	3,147	38%	3,144	38%	3,414	38%
Total	25,552	100%	8,338	100%	8,343	100%	8,871	100%
Missing	*5,243*	*(17%)*	*1,585*	*(16%)*	*1,862*	*(18%)*	*1,796*	*(17%)*
Stage								
I	12,019	52%	3,835	51%	4,135	52%	4,049	52%
II	1,517	7%	482	6%	505	6%	530	7%
III	4,916	21%	1,542	21%	1,619	20%	1,755	22%
IV	4,818	21%	1,620	22%	1,689	21%	1,509	19%
Total	23,270	100%	7,479	100%	7,948	100%	7,843	100%
Missing	*7,525*	*(24%)*	*2,444*	*(25%)*	*2,257*	*(22%)*	*2,824*	*(26%)*
T stage								
T1	14,297	59%	4,631	59%	4,841	60%	4,825	59%
T2	2,351	10%	772	10%	798	10%	781	10%

Table A2. Patient characteristics for people newly diagnosed with kidney cancer in England over the period of 1 January 2021 - 31 December 2023.								
Data variable	**England**							
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Time period covered	***1 Jan 2021 - 31 Dec 2023***		***2021***		***2022***		***2023***	
T3	6,724	28%	2,194	28%	2,183	27%	2,347	29%
T4	737	3%	232	3%	253	3%	252	3%
Total	24,109	100%	7,829	100%	8,075	100%	8,205	100%
Missing	*6,686*	*(22%)*	*2,094*	*(21%)*	*2,130*	*(21%)*	*2,462*	*(23%)*
N stage								
N0	20,184	91%	6,437	90%	6,836	91%	6,911	92%
N1	1,961	9%	701	10%	662	9%	598	8%
Total	22,145	100%	7,138	100%	7,498	100%	7,509	100%
Missing	*8,650*	*(28%)*	*2,785*	*(28%)*	*2,707*	*(27%)*	*3,158*	*(30%)*
M stage								
M0	18,943	81%	6,004	80%	6,397	80%	6,542	82%
M1	4,572	19%	1,548	21%	1,594	20%	1,430	18%
Total	23,515	100%	7,552	100%	7,991	100%	7,972	100%
Missing	*7,280*	*(24%)*	*2,371*	*(24%)*	*2,214*	*(22%)*	*2,695*	*(25%)*
Ethnicity								
Asian or Asian British	1,137	4%	348	4%	366	4%	423	4%
Black, Black British, Caribbean or African	788	3%	247	3%	259	3%	282	3%
Mixed or multiple ethnic groups	228	1%	65	1%	71	1%	92	1%
White	26,871	91%	8,776	91%	8,904	91%	9,191	90%
Other	646	2%	163	2%	230	2%	253	2%
Total	29,670	100%	9,599	100%	9,830	100%	10,241	100%
Missing	*1,125*	*(4%)*	*324*	*(3%)*	*375*	*(4%)*	*426*	*(4%)*
Indices of multiple deprivation (IMD) of LSOA								
1 (least deprived)	6,311	20%	2,019	20%	2,089	20%	2,203	21%
2	6,508	21%	2,111	21%	2,151	21%	2,246	21%
3	6,322	21%	2,041	21%	2,119	21%	2,162	20%
4	5,846	19%	1,863	19%	1,957	19%	2,026	19%
5 (most deprived)	5,808	19%	1,889	19%	1,889	19%	2,030	19%
Total	30,795	100%	9,923	100%	10,205	100%	10,667	100%
Missing	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*

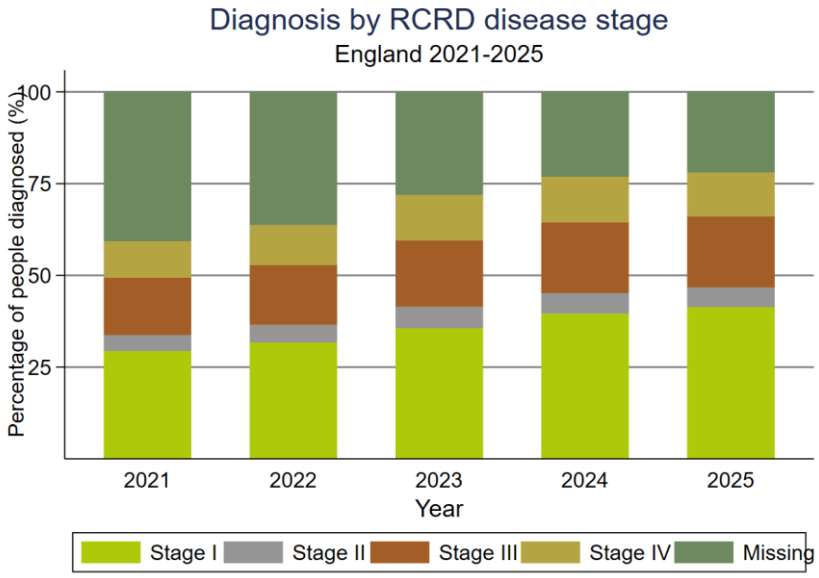
LSOA: Lower Layer Super Output Areas.

*Performance status: 0 = Able carry out all normal activity without restriction; 1 = Restricted in physically strenuous activity, but able to walk and do light work; 2 = Able to walk and capable of all self care, but unable to carry out any work. Up and about more than 50% of waking hours; 3 = Capable of only limited self care, confined to bed or chair more than 50% of waking hours; 4 = Completely disabled. Cannot carry on any self care. Totally confined to bed or chair.

Table A3. Performance indicators for people with kidney cancer diagnosed and treated in England by year from 2019 to 2023.					
	2019	**2020**	**2021**	**2022**	**2023**
PI1: Percentage of people with kidney cancer with a recorded MDT meeting date (data completeness measure)	83%	82%	81%	83%	86%
PI2: Percentage of people with kidney cancer consented for a clinical trial	2%	1%	2%	2%	1%
PI3: Percentage of people with a small kidney cancer who have a biopsy	23%	20%	22%	22%	21%
PI4: Percentage of people with a T3+ and/or 10cm+ and/or N1 and M0 renal cell carcinoma (RCC)** whose radical nephrectomy is within 31 days of decision to treat	81%	78%	73%	67%	64%
PI5: Percentage of people with T1b-3NXM0 RCC** who have surgery 1 month prior and 12 months following diagnosis*	81%	76%	78%	78%	79%
PI6: Percentage of people with T1aN0M0 RCC** who undergo nephron sparing treatment 1 month prior and 12 months following diagnosis*	69%	68%	72%	71%	71%
PI7: Percentage of people with metastatic RCC receiving initial SACT within 12 months of diagnosis*	48%	48%	52%	50%	54%
PI8: Percentage of people with kidney cancer who die within 30 days of starting SACT treatment	3%	2%	2%	2%	1%
MDT: multi-disciplinary team; RCC: renal cell carcinoma; SACT: systemic anti-cancer therapy. *12 months following diagnosis was measured to capture all people with kidney cancer who underwent treatment. Timeframe to treatment was not assessed in these performance indicators. ** UICC TNM8 Kidney Cancer. Data were impacted by the COVID-19 pandemic and so will be atypical to some degree during 2020-2021.					

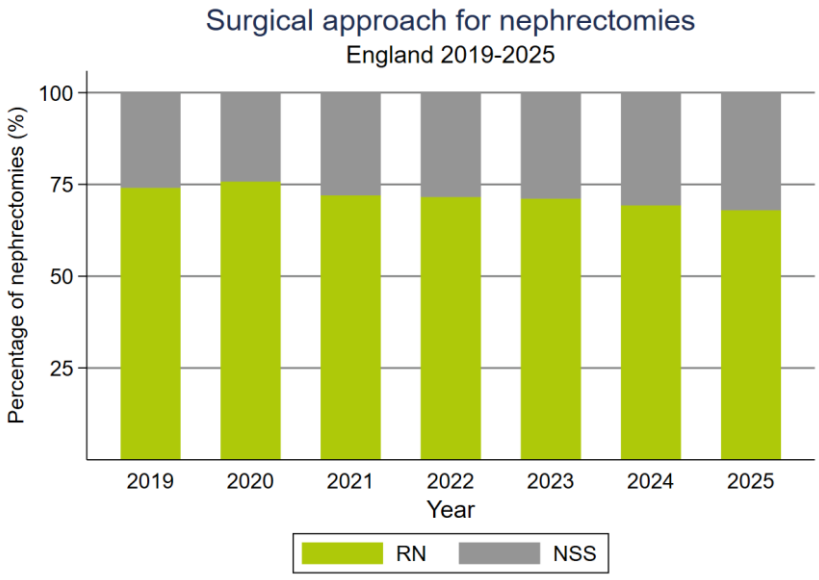
T3+ and/or 10cm+ and/or N1 and M0 RCC	Tumour extends into major veins or perinephric tissues or invades beyond Gerota fascia and/or tumour more than 10cm in size and/or metastasis in regional lymph node(s) with no distant metastasis
T1b-3NXM0 RCC	Tumour is more than 4cm in size or tumour extends into major veins or perinephric tissues with no distant metastasis
T1aN0M0 RCC	Tumour is less than or equal to 4cm in size with no regional lymph node metastasis and no distant metastasis

Figure A1. Diagnosis by RCRD disease stage in England from 1st January 2021 to 31st October 2025.



RCRD: Rapid Cancer Registration Dataset. 2025 data includes people diagnosed until 31st Oct 2025.

Figure A2. Proportion of radical nephrectomies (RNs) vs nephron sparing surgery (NSSs) in England from 1st January 2019 to 30th September 2025.



2025 data includes people diagnosed until 30th Sep 2025.

Table A4. Patient characteristics for people newly diagnosed with kidney cancer in Wales over the period of 1 January 2022 - 31 December 2024.								
Data variable	**Wales**							
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Time period covered	***1 Jan 2022 - 31 Dec 2024***		***2022***		***2023***		***2024***	
No. of people with new diagnosis of kidney cancer	1,429		488		492		446	
Age								
<45	60	4%	18	4%	25	5%	17	4%
45-54	132	9%	44	9%	52	11%	36	8%
55-64	345	24%	110	23%	127	26%	107	24%
65-74	437	31%	143	29%	147	30%	146	33%
75-84	361	25%	132	27%	112	23%	117	26%
>85	94	7%	41	8%	28	6%	25	6%
Total	1,429	100%	488	100%	491	100%	448	100%
Missing	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*	*0*	*(0%)*
Gender (Self-stated gender at diagnosis)								
Male	925	66%	308	65%	310	64%	305	68%
Female	486	34%	169	35%	174	36%	143	32%
Total	1,411	100%	477	100%	484	100%	439	100%
Missing	*18*	*(2%)*	*11*	*(2%)*	*7*	*(1%)*	*0*	*(0%)*
Performance status*								
0	567	47%	161	47%	201	44%	205	51%
1-2	541	45%	142	41%	220	49%	179	44%
≥3	94	8%	41	12%	32	7%	21	5%
Total	1,202	100%	344	100%	453	100%	405	100%
Missing	*227*	*(16%)*	*144*	*(30%)*	*38*	*(8%)*	*43*	*(10%)*
Number of co-morbidities (Charlson score)								
0	636	53%	208	51%	211	52%	217	56%
1	231	19%	70	17%	77	19%	84	22%
≥2	333	28%	128	32%	120	29%	85	22%
Total	1,200	100%	406	100%	408	100%	386	100%
Missing	*229*	*(16%)*	*82*	*(17%)*	*83*	*(17%)*	*62*	*(14%)*
Stage								
I	556	45%	162	43%	212	45%	182	47%
II	123	10%	41	11%	54	12%	28	7%
III	310	25%	95	25%	97	21%	118	31%
IV	237	19%	76	20%	103	22%	58	15%
Total	1,226	100%	374	100%	466	100%	386	100%
Missing	*203*	*(14%)*	*114*	*(23%)*	*25*	*(5%)*	*62*	*(14%)*
T stage								
T1	581	48%	168	46%	220	48%	193	51%
T2	157	13%	54	15%	71	16%	32	8%
T3	389	32%	116	32%	129	28%	144	38%
T4	74	6%	26	7%	35	8%	13	3%
Total	1,201	100%	364	100%	455	100%	382	100%

Table A4. Patient characteristics for people newly diagnosed with kidney cancer in Wales over the period of 1 January 2022 - 31 December 2024.								
Data variable	**Wales**							
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Time period covered	***1 Jan 2022 - 31 Dec 2024***		***2022***		***2023***		***2024***	
Missing	*228*	*(16%)*	*124*	*(25%)*	*36*	*(7%)*	*66*	*(15%)*
N stage								
N0	938	85%	278	84%	340	83%	320	88%
N1	165	15%	52	16%	71	17%	42	12%
Total	1,103	100%	330	100%	411	100%	362	100%
Missing	*326*	*(23%)*	*158*	*(32%)*	*80*	*(16%)*	*86*	*(19%)*
M stage^								
M0	872	80%	247	79%	306	76%	319	86%
M1	217	20%	67	21%	97	24%	53	14%
Total	1,089	100%	314	100%	403	100%	372	100%
Missing	*340*	*(24%)*	*174*	*(36%)*	*88*	*(18%)*	*76*	*(17%)*
Ethnicity								
All other ethnic groups combined**	21	3%	8	3%	5	2%	8	3%
White	761	97%	275	97%	243	98%	241	97%
Total	782	100%	283	100%	248	100%	249	100%
Missing	*647*	*(45%)*	*205*	*(42%)*	*243*	*(49%)*	*199*	*(44%)*
Indices of multiple deprivation (IMD) of LSOA								
1 (least deprived)	255	18%	79	16%	93	19%	83	19%
2	317	22%	110	23%	115	24%	92	21%
3	316	22%	97	20%	115	24%	103	23%
4	286	20%	111	23%	87	18%	87	19%
5 (most deprived)	246	17%	88	18%	75	15%	83	19%
Total	1,420	100%	485	100%	485	100%	448	100%
Missing	*9*	*(1%)*	*3*	*(1%)*	*6*	*(1%)*	*0*	*(0%)*

LSOA: Lower Layer Super Output Areas.

*Performance status: 0 = Able carry out all normal activity without restriction; 1 = Restricted in physically strenuous activity, but able to walk and do light work; 2 = Able to walk and capable of all self care, but unable to carry out any work. Up and about more than 50% of waking hours; 3 = Capable of only limited self care, confined to bed or chair more than 50% of waking hours; 4 = Completely disabled. Cannot carry on any self care. Totally confined to bed or chair.

^ People who would have been coded as MX in the old Welsh database (CaNISC) are now coded as M0 in the new system (CDF). The transition to the new system began in 2023, and as of mid-2026 NHS Wales are encouraging people with unknown metastatic status (previously coded as MX or missing) to be coded as missing instead of M0.

** All other ethnic groups combined includes, Asian or Asian British, Black, Black British, Caribbean or African, Mixed or multiple ethnic groups and Other ethnicity groups. Individual ethnic groups were collapsed due to small numbers.

Figure A3. Diagnosis by disease stage in Wales in 2022 - 2024.

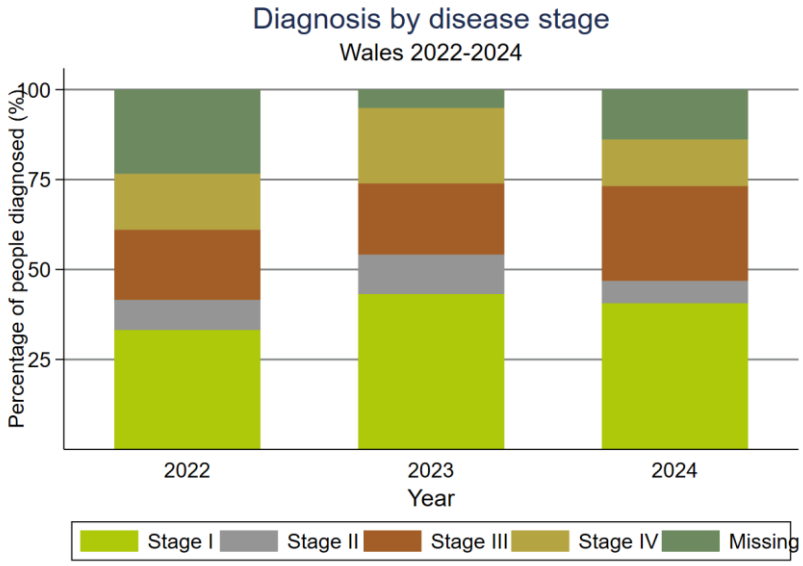


Table A5. Performance indicators for people with kidney cancer diagnosed and treated in Wales by year from 2022 to 2024.			
	2022	**2023**	**2024**
PI1: Percentage of people with kidney cancer with a recorded MDT meeting date (data completeness measure)	>99%	99%	97%
PI5: Percentage of people with T1b-3NXM0^ RCC** who have surgery 1 month prior and 12 months following diagnosis*	80%	86%	83%
PI7: Percentage of people with metastatic RCC receiving initial SACT within 12 months of diagnosis*	56%	54%	65%
PI8: Percentage of people with kidney cancer who die within 30 days of starting SACT treatment	2%	0%	0%
MDT: multi-disciplinary team; RCC: renal cell carcinoma; SACT: systemic anti-cancer therapy. ^ People who would have been coded as MX in the old Welsh database (CaNISC) are now coded as M0 in the new system (CDF). The transition to the new system began in 2023, and as of mid-2026 NHS Wales are encouraging people with unknown metastatic status (previously coded as MX or missing) to be coded as missing instead of M0. *12 months following diagnosis was measured to capture all people with kidney cancer who underwent treatment. Timeframe to treatment was not assessed in these performance indicators. ** UICC TNM8 Kidney Cancer.			

Ongoing methodology developments

1. Improving timeliness of reporting in England

It is a high priority for the NKCA to explore whether we can make our State of the Nation performance indicators (PIs) more timely. We use the National Cancer Registration Dataset (NCRD) to generate our PI results as it is the 'gold standard' cancer registration dataset in England. NCRD is available two years after diagnosis. However, an alternative, more timely data source is the Rapid Cancer Registration Dataset (RCRD) which is available four months after diagnosis. There are NATCAN audits that report some or all of their PIs using RCRD. However, there are some kidney cancer specific challenges. Primarily, the delay and completeness of TNM and lesion size data in RCRD.

1.1 Under- and over-capture

We compared the most recent NCRD extract with the earliest RCRD extract that covers the same cohort (people diagnosed with kidney cancer between January 2021 and December 2023). This is to simulate what would happen if we used the latest RCRD extract available to us. The NCRD extract was received in November 2025 and the RCRD extract was received in May 2024. Table A6 displays the number of people captured in both datasets as well as the number of people only captured in one.

Table A6. Number of people diagnosed with kidney cancer in 2021-2023 present in the November 2025 NCRD extract and/or the May 2024 RCRD extract.

	Present in NCRD (Confirmed registrations)	**Absent from NCRD**	
Present in RCRD (Provisional registrations)	24,586	2,859 (**10% over capture**)	*RCRD total:* 27,445
Absent in RCRD	6,322 (**20% under capture**)	N/A	
	NCRD total: 30,908		

NCRD, National Cancer Registration Dataset; RCRD, Rapid Cancer Registration Dataset.

Of the confirmed registrations in NCRD, 20% were absent from the RCRD extract. Of the provisional registrations in RCRD, 10% were absent from the NCRD extract. This suggests there is 20% under-capture and 10% over-capture in RCRD. This was consistent across all three years. By comparison, the National Prostate Cancer Audit reported an under-capture of 10% and over-capture of 3%[1].

1.2 Performance indicator results

The national results for three performance indicators (PI3, PI4 and PI7) were calculated using NCRD and RCRD. These three PIs were selected due to clinical interest and as they encompass different points in the patient pathway. The national averages calculated using RCRD and NCRD were similar (Table A7). However, the numerators and denominators were lower (to varying degrees) using RCRD.

Table A7. Performance indicator national results calculated using November 2025 NCRD and May 2024 RCRD.

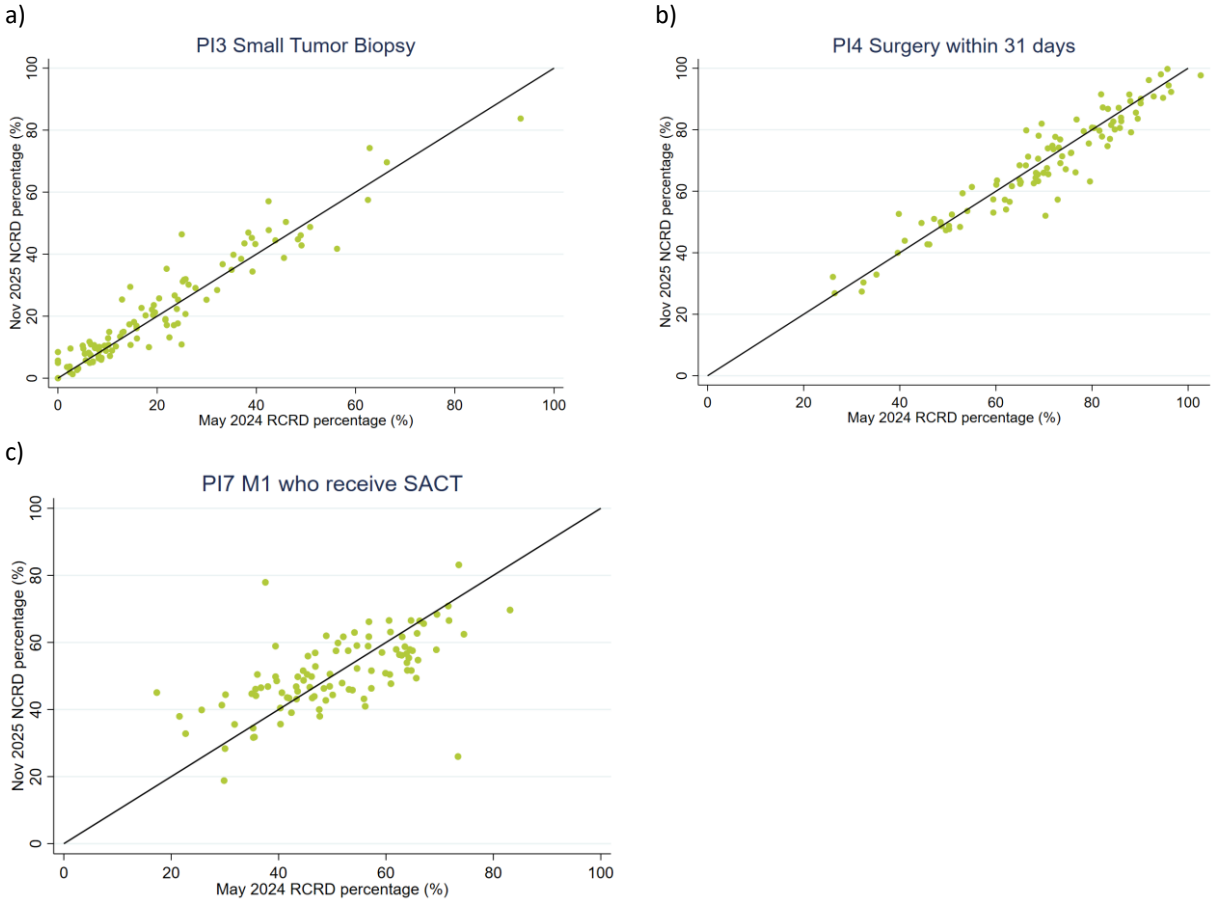
PI	**Data Source**	**National Average**	**Denominator**	**Numerator**
PI3 Small kidney cancer biopsy	Nov 2025 NCRD	21%	9,175	1,967
	May 2024 RCRD	19%	5,463	1,064
PI4 Surgery within 31 days	Nov 2025 NCRD	68%	4,354	2,959
	May 2024 RCRD	69%	3,823	2,645
	Nov 2025 NCRD	50%	7,587	3,824

[1] National Prostate Cancer Audit (NPCA). NPCA: Methodological Update 2023: Comparison of National Cancer Registration Dataset and Rapid Cancer Registration Dataset. NPCA Methodological Update 2023 - National Cancer Audit Collaborating Centre

PI7 SACT for M1 disease	May 2024 RCRD	51%	2,984	1,534
NCRD, National Cancer Registration Dataset; RCRD, Rapid Cancer Registration Dataset; SACT, systemic anti-cancer therapy.				

At the provider level, the agreement in the PI results (percentages) calculated using NCRD and RCRD was good for PI3 and PI4 (Figure A4a and A4b). The agreement was poor for PI7 (Figure A4c). Despite overall good agreement for PI3 and PI4, reporting the results of the providers furthest from the line of perfect agreement could be misleading. There were providers where there was a 10-20% absolute difference in their RCRD and NCRD percentages. For example, their RCRD result was 25% and their NCRD result was 45% or vice versa.

Figure A4. Scatter plots depicting agreement in provider-level performance indicator results a) PI3 b) PI4 c) PI7.



NCRD: National Cancer Registration Dataset, RCRD: Rapid Cancer Registration Dataset, SACT: systemic anti-cancer therapy.

We will continue this work in the hope that we can use RCRD to improve the timeliness of our State of the Nation PI reporting in the future. Our next steps include further understanding the under- and over-captured people. We will explore rules to remove over-captured people from RCRD and assess whether this improves the agreement of PI reporting at the provider level.

Please note Wales wasn't included in this methodological work as the data we use to generate PI results for Wales is more timely than NCRD and there isn't currently an equivalent dataset to RCRD for Wales. However, NHS Wales Performance and Improvement are working on further improving the timeliness of their data delivery to us.

2. An alternative approach to estimate the national distribution of performance

2.1 Rationale

NKCA uses funnel plots to identify statistical outliers (i.e., performance outside control limits representing sampling variability). Most of our performance indicators (PI3-PI8) are computed using risk-adjusted models and indirect standardisation. While this is a valid approach to identifying outliers, sampling variability can limit meaningful comparisons between providers, and the national distribution of performance can be inflated (hence why min/max ranges have not been included in this report).

Here we pilot the use of mixed-effects models, accounting for differences between providers (such as case volume) and partially separating true provider differences from sampling variability through shrinkage of noisy (small provider) estimates toward the mean. These models have several applications, including facilitating estimation of a more stable national distribution of provider performance.

2.2 Estimated distribution of national performance

We simulated the expected distribution of performance using mixed-effects models incorporating clustering by provider. Repeated 1,000 times, each simulation combined uncertainty in model parameters, between-provider variation and variability in provider case-mix and volume by repeatedly drawing different patient samples. This yielded a national distribution of providers' average predicted probabilities (Table A8).

For example, the IQR for the percentage of people with T1aN0M0 RCC who undergo nephron sparing treatment (PI6) is 62% to 79%. While similar to the IQR of indirectly standardised estimates (59%-81%), the advantages of using mixed-effects modelling are more likely to be evident when there are many small providers, substantial variation in provider case volume/mix, or when the outcome is rare (i.e., scenarios where indirect standardisation is more sensitive to sampling variability). Furthermore, while simulations provide a more robust way to capture both data and model-based uncertainty, the close alignment to the estimates without simulation suggests that the underlying performance distribution is relatively stable, likely reflecting the large dataset and modest between-provider variation.

Table A8. Comparing the national distribution of performance (median [interquartile range]) using different approaches.

	Indirect standardisation	**Mixed-effects modelling**	
		without simulations*	**with simulations**
PI1	85.4% [74.2%-91.2%]**	84.6% [75.3%-90.8%]	84.6% [75.3%-90.9%]
PI2	1.1% [0.0%-2.2%]**	1.2% [0.8%-1.8%]	1.2% [0.8%-1.8%]
PI3^	17.3% [9.5%-34.9%]	17.3% [8.6%-31.8%]	18.7% [9.4%-33.4%]
PI4	68.8% [56.6%-80.7%]	70.9% [58.7%-80.7%]	70.6% [58.4%-80.4%]
PI5^	79.3% [71.9%-83.3%]	82.5% [76.4%-87.3%]	78.7% [72.3%-84.1%]
PI6	71.3% [59.4%-81.3%]	71.9% [62.7%-79.6%]	71.1% [61.9%-78.9%]
PI7^	50.4% [43.6%-58.2%]	48.9% [41.2%-56.6%]	51.0% [43.7%-58.2%]
PI8^	1.4% [0.0%-2.5%]	1.7% [1.4%-2.0%]	1.9% [1.6%-2.3%]

*Estimates derived by constructing a normal distribution around the national average performance ± between-provider standard deviation.
**PI1/PI2 are not risk-adjusted and therefore are not indirectly standardised.
^English and Welsh data analysed together (all others are England only).

2.3 Other applications

We plan to extend this modelling framework to support quality assessment by estimating the probability that a provider's performance is below the national mean, quality assurance by pairing lower- and higher-performing providers, and quality improvement by estimating the probability of achieving performance targets.

Glossary

Radical nephrectomy
The surgical removal of an entire kidney to treat kidney cancer. The adrenal gland which is a small triangular shaped gland located on top of each kidney is left behind if not involved with the kidney cancer. It produces hormones to help regulate metabolism.

Partial nephrectomy
The surgical removal of part of the kidney which contains the kidney cancer. The goal is to remove the diseased portion while preserving as much of the healthy kidney tissue as possible.

Thermal ablation
Thermal ablation is the used to treat small kidney cancers by using extreme heat or cold to destroy cancer cells. Radiofrequency Ablation (RFA): Uses high-energy radio waves to generate heat that destroys cancer cells. Microwave ablation (MWA): Uses microwave energy to generate heat and destroy cancer cells. Cryoablation: Uses extreme cold to freeze and kill cancer cells.

Nephron sparing treatment
Can be used to describe both partial nephrectomy and thermal ablation, as both involvement treatment of the kidney cancer while preserving the healthy kidney tissue.

Renal biopsy
A procedure where small piece of kidney tissue is removed for examination under a microscope to determine the presence of kidney cancer and help guide treatment.

Metastatic disease
When cancer has spread from its initial site of development in the kidney (the primary site) to distant sites of the body (the metastatic site(s)). The diagnosis is usually made by imaging tests.

Systemic therapy
Systemic therapy is anti-cancer drug therapy. This includes novel targeted therapies (i.e. Pembrolizumab, Nivolumab, Ipilimumab, Cabozantinib, Axitinib, Lenvatinib) for kidney cancer.

Radiotherapy
The use of radiation to destroy cancer cells. Since cancer cells grow and divide quickly, radiation disrupts their growth, leading to their destruction. There are different types of radiotherapy, including stereotactic ablative radiotherapy (SABR) and external beam radiotherapy (EBRT). SABR uses high doses of radiation delivered in fewer sessions and can be used to treat kidney cancer in selected situations. EBRT can be used to treat kidney cancer when it has spread to other parts of the body.

Staging/stage
The anatomical extent of a cancer. This indicates whether a cancer is only present in the kidney/primary site (localised disease) or whether it has spread to other areas of the body (metastatic spread). It is usually denoted by the TNM staging process where “T” represents the local stage, “N” the presence of lymph node involvement and “M” represents the presence of metastatic disease.

T1 is divided into T1a and T1b depending on how big the cancer is:

- T1a means the cancer measures 4cm or less
- T1b means the cancer measures between 4cm and 7cm

T2 is divided into T2a and T2b depending on size:

- T2a means the cancer measures between 7cm and 10cm
- T2b means the cancer measures more than 10cm but completely inside the kidney

T3 is divided into T3a, T3b and T3c depending on whether the cancer has grown into surrounding tissues or main blood vessels:

- T3a means the cancer has grown into the nearby tissues or the renal vein

- T3b means the cancer has grown into the vena cava, but hasn't spread above the diaphragm (sheet of muscle that separates chest and abdominal cavity, which helps us breathe)
- T3c means the cancer has grown into the vena cava and spread above the diaphragm. Or has grown into the wall of the vena cava.

T4 means the cancer has spread beyond the layer of tissue around the kidney (fascia). It might have spread into the adrenal gland above the kidney.
N0 means that the nearby lymph nodes do not contain cancer cells
N1 means there are cancer cells in lymph nodes near the kidney
M0 means the cancer has not spread to other parts of the body
M1 means the cancer has spread to other parts of the body such as the lungs

Indirect standardisation
A method for adjusting provider-level performance for differences in case-mix by comparing observed performance to model-based expectations. For each provider, the observed proportion is divided by the expected proportion and then multiplied by the overall national observed proportion. This approach compares a provider's observed performance to what would be expected if it performed at the national average, given its case-mix.

Sampling variability
The natural variation in estimates that arises because results are based on a sample, reflecting random differences that occur when the sampling is repeated each year.

Mixed-effects model
A statistical model that includes both fixed effects (parameters that are constant across all patients) and random effects (parameters that vary across providers). Random effects represent provider-specific deviations from the overall population average. A mixed-effects model can include random intercepts (allowing each provider to have a different baseline level of the outcome) and/or random slopes (allowing the relationship between predictors and the outcome to vary by provider).