Abdominal non-contrast CT scanning to screen for kidney cancer and other abdominal pathology within community-based CT screening for lung cancer: results of the Yorkshire Kidney Screening Trial

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Abstract

Background and objectives

The Yorkshire Kidney Screening Trial (YKST) assessed the feasibility of adding abdominal non-contrast CT (NCCT) to lung cancer screening to screen for kidney cancer and other abdominal pathology.

Methods

Prospective diagnostic study offering abdominal NCCT to 55-80y ever-smokers attending a UK randomised lung cancer screening trial (May 2021-October 2022). Exclusion criteria: dementia, frailty, previous kidney/lung cancer, CT abdomen/thorax within previous 6/12 months respectively. 6 months follow-up was undertaken.

Key findings and limitations

4438 people attended lung screening, of whom 4309 (97%) were eligible for and 4019 (93%) accepted abdominal NCCT. Only 3.9% respondents regretted participating. The additional time to conduct the YKST processes was 13.3mins.

2586 (64%) of participants had a normal abdominal NCCT, whilst 787 (20%) required abdominal NCCT imaging review but no further action and 611 (15%) required further evaluation (investigations and/or clinic). 211 (5.3%) participants had a serious finding, including: 25 (0.62%) with a renal mass/complex cyst, of which 10 (0.25%) had histologically-proven kidney cancer; 10 (0.25%) with other cancers; and 60 (1.5%) with abdominal aortic aneurysms (AAA). 25 (0.62%) participants had treatment with curative intent. 1017 (25%) participants had non-serious findings, most commonly benign renal cysts (727 (18%)), whereas only 259 (6.4%) had non-serious findings requiring further tests. The number needed to screen to detect one serious abdominal finding was 18, to detect one suspicious renal lesion was 93 and to detect one histologically confirmed renal cancer 402. Limitations of the cohort were fixed age-range, prior lung screening attendees.

Conclusions and clinical implications

In this first prospective risk-stratified screening study of abdominal NCCT offered alongside CT thorax, uptake and participant satisfaction were high. Prevalence of serious findings, cancers and AAA, is in the range of

established screening programmes such as for bowel cancer. Longer-term outcomes and cost-effectiveness should now be evaluated.

Trial Registration

ClinicalTrials.gov: NCT0500519

Patient summary

We performed a trial to assess adding abdominal CT scanning onto CT scan-based lung cancer screening, to screen for kidney cancer and other serious abdominal abnormalities. The trial showed this approach is achievable and acceptable and detects relevant serious abdominal findings at a high enough level for the approach to be considered for further evaluation as to whether it should be widely implemented.

Advancing Practice

The Yorkshire Kidney Screening Trial demonstrated the feasibility of adding abdominal non-contrast CT to lung cancer screening to screen for kidney cancer and other abdominal pathology. Participant satisfaction and uptake were both high. The prevalence of serious findings, most notably abdominal cancers and AAA, was in the range of established screening programmes.These findings suggest further research evaluating disease stage-shift and/or disease specific survival as well as cost-effectiveness should be conducted.

Introduction

Early detection of cancer allows the best chance of cure using effective treatments [1,2]. Targeted lung cancer screening exists in the USA and UK for high-risk ever-smokers [3,4]. Adding additional tests alongside lung cancer screening provides an opportunity to screen for other diseases, where stand-alone screening programmes would be unlikely to be cost-effective due to relatively low prevalence [5,6]; however, the feasibility of such a paradigm has never previously been tested. One such disease is kidney cancer (renal cell cancer [RCC]), for which smoking is a risk-factor shared with lung cancer [1]. RCC is often asymptomatic leading to late diagnosis; however, if detected early, is largely curable (95% disease free at 10 years) [1,7]. Clinicians and patients identified screening as one of the highest priorities in kidney cancer research [8]. RCC screening could largely comply with Wilson and Jungner screening criteria including cost-effectiveness [9,10].

The Yorkshire Kidney Screening Trial (YKST; NCT05005195) assessed the feasibility of adding abdominal non-contrast CT (NCCT) to screen for RCC and other abdominal pathology within an ongoing randomised trial of community-based lung cancer screening, the Yorkshire Lung Screening Trial (YLST; NCT03750110)[11,12]. We report uptake and acceptability of abdominal NCCT within YKST and prevalence of findings.

Methods

Study design and participants

YKST recruited from YLST participants who attended a second YLST study visit (T2), between 10th May 2021-26th October 2022, two years after baseline T0 lung screening. YLST eligibility was 55-80 years and: ever-smokers; not living in a nursing home or housebound; no dementia/frailty; no lung cancer within past 5-years; no previous metastatic cancer; no CT thorax within previous 12-months; not on palliative care register. Those at high-risk for lung cancer, defined by USPSTF (≥30 pack years and smoked within 15-years), PLCO ($PLCO_{M2012}$ score ≥1.51%) or LLP (LLP_{v2} ≥5%) criteria were invited for CT thorax [12]. Additional YKST inclusion criteria: attending the unit for YLST T2 visit, could provide informed consent; exclusion criteria: abdominal CT within last 6-months, unable to have abdominal NCCT, previous RCC. YKST ethics approval was granted by the North-West-Preston Research Ethics Committee (21/NW/0021).

Procedures

Detailed procedures in Supplementary Methods. Eligible T2 YLST participants declining YKST were invited to provide a brief reason.

As part of a sub-study aimed to assess the views of the participants of the study and the non-physical harms resulting from the scan, 500 participants, comprising all who had an abnormal abdominal CT scan and a random sample of one-third of those with a normal scan (14th March 2022-24th August 2022), were sent a questionnaire (supplementary file) at three-months including questions asking about process satisfaction and decisional regret scale [13]. Based on those scanned at the start of the study, we estimated that approximately 20% would have an abnormal scan requiring no further action, approximately 20% would have an abnormal scan requiring further action and 60% of participants would have a normal scan; hence one-third of those with normal scans being randomly sampled to allow comparison of equal numbers of participants from each group. The selection of those with a normal scan was undertaken by numbering participants with normal scans in the order in which they were scanned and selecting them based on random numbers from a random number generator until we reached the quota of 500 participants invited. The decision to invite 500 participants was based on pragmatic considerations and the primary objective of that sub-study (to compare the psychological impact of the abdominal scan between those three groups). An *a priori* power calculation performed estimated that we would have 80% power to detect a difference in psychosocial impact of 0.32 SD between

those with a normal CT and those with an abnormal CT not requiring further action and 80% power to detect a difference in psychosocial impact of 0.84 SD between those with a normal CT and those with an abnormal CT requiring further action.

Consenting participants had the abdominal NCCT scan during their T2 YLST visit. The scan, from the diaphragm to the bottom of the kidneys, was obtained separately from the CT thorax. Radiation exposure was iteratively reduced throughout YKST and scan quality assessed (Supplementary Methods). Each element of the combined screening was timed on one day by one researcher (AG).

Participants with normal scans were automatically sent 'normal scan' letters and not further reviewed. Remaining participants were reviewed in an Imaging Review Meeting (IRM) and one-of-five triaging options applied: letter of reassurance for benign findings requiring no further action, reconnect with a clinic for a known or related problem, referral to a new non-urology clinic, referral to a urology clinic or referral for a CT with MDT review. Henceforth, patients were managed as per standard-of-care in a UK tertiary referral centre. Patients with suspected/proven RCC were managed as per EAU guidelines [14].

For all participants with an abnormal abdominal NCCT, electronic health records were reviewed at 6 months, and findings categorised into serious or non-serious based on the final diagnosis. Serious findings were defined as carrying a real prospect of seriously threatening life span, or having a substantial impact on major bodily functions or quality of life based on previous published recommendations, expert recommendations or national guidelines (Table S1)[15].

Outcomes

Primary objectives of YKST were:

- Quantify uptake of abdominal NCCT to screen for RCC and other abdominal pathology as part of a combined screening modality with LDCT thorax within a lung health check;
- Assess acceptability to participants of combined lung and RCC screening by abdominal NCCT scanning;
- Assess the logistics and pilot the majority of procedures of RCC screening by abdominal NCCT scanning within lung cancer screening, specifically:
    - Additional time required at each stage of the combined screening approach;
    - Abdominal NCCT scan dose, quality and number of rescans required;

- Reporting patterns and agreement of radiologists;
- Clinical workload created.

Secondary objectives were to determine:

- Prevalence and stage distribution of renal masses/RCCs;
- Prevalence of incidental renal findings;
- Prevalence of non-renal findings;
- Incidence of renal masses/RCCs in the upper pole kidney over sequential LDCT thorax.

Statistical analysis

The final sample size was dependent on attendance at YLST T2. In study planning we anticipated inviting 4700 participants (with 80-90% of those consenting to participate [11]), therefore estimating the primary outcome (uptake of the scan) to within 1%. In practice, we invited slightly fewer participants (n=4309) but uptake was higher than anticipated, allowing us to estimate scan uptake with greater precision to within 0.8%.

Multivariable logistic regression was performed using individual level participant data to assess the participant level characteristics associated with uptake of the abdominal NCCT. Unadjusted and adjusted odds ratios (OR) with 95% confidence intervals (CIs) were calculated using a complete case approach.

In the non-physical harms sub-study we report the percentage ‘very satisfied’ or ‘satisfied’ etc by scan result and then an overall percentage weighted for the distribution of scan results across the whole cohort.

Analysis of reasons for declining abdominal NCCT are in supplementary methods.

Results

Acceptability

4438 people attended YLST T2; 4309 (97%) were eligible and invited to participate in YKST. Of those, 4019 (93%, 95%CI:93-94%) consented to participate in YKST (Figure 1). Older individuals (OR:0.55 per 10-year increase in age [95%CI:0.45-0.66; p<0.001]), women (0.76 [0.60-0.97]; p=0.028) and current smokers (0.67 [0.51-0.87]; p=0.003) were significantly less likely to participate (Table S2).

Of those declining the scan, 116 (40%) provided reasons (Table 1). Nearly half declined because of personal health beliefs, most commonly because they believed they were already in a kidney care pathway or felt their kidneys were 'okay'. Eighteen respondents (16% of decliners) cited reasons related to the CT scan, with concerns about radiation exposure and claustrophobia. Nine percent (n=11) responded that they might consider the scan in the future or would have accepted were they given more time to consider participation.

380/500 (76%) responded to the 3-month questionnaire: 154 with normal scans, 129 with abnormal scans requiring no further action and 97 with abnormal scans requiring further action. Weighting responses in those three groups based on the proportion of participants with normal and abnormal scans across the full cohort (Table S3), 93% were 'satisfied' or 'very satisfied' with the information provided, 98% thought they 'probably' or 'definitely' had sufficient time to decide to participate and 96% were 'satisfied' or 'very satisfied' with the way results were given. 97% 'agreed' or 'strongly agreed' they had made the right decision in participating, whilst only 3.9% 'agreed' or 'strongly agreed' that they regretted their decision to participate in YKST.

Responses were similar across the three groups but the proportions satisfied with the information provided and time provided were lower amongst those with abnormal scans requiring further action and that group were also more likely to have regretted the decision to participate in YKST (4/133 (3.0%) of those with normal scans, 4/106 (3.8%) of those with abnormal scans requiring no further action at IRM, and 7/86 (8.1%) of those with an abnormal scan requiring further action at IRM).

Feasibility

Figure S1 details the process steps of YKST and additional time taken to achieve these. The mean total additional time, involving unit staff, was 13.3mins (standard deviation 1.1).

Abdominal NCCT radiation dose was iteratively reduced (Table S4) to reach the final median dose of 4mGy which was below the National and Local reference levels for a standard NCCT kidney/ureter/bladder of 10mGy

and 5.3mGy respectively. The quality of all scan dose iterations was acceptable and the median for all iterations graded as 'excellent' (Table S4). Table S5 details the comparable reporting patterns of the three YKST radiologists. Median time from scan-to-reporting was 5 days (IQR-3-8) and scan-to-result letter sent was 8 days (IQR-6-12).

Prevalence of abdominal findings

Unless specified, results refer to new findings seen only on the abdominal NCCT and not identified on lower slices of the CT thorax. Figure 1 summarises outcomes of the abdominal NCCTs and the new workload created. 2586 (64%) participants were sent letters informing them of a normal scan. 1213 (30%) scans were reviewed at an IRM. 546 participants (45% discussed, 14% all participants) required further evaluation. This resulted in 723 investigations in 370 (9.2%) participants. YKST triggered 63 procedures in 52 (1.3%) patients (Table S6&S7), of which 22 were diagnostic such as endoscopies or percutaneous biopsies. Twenty-five (0.62% participants) had treatment with curative intent (i.e. surgery, thermal ablation, embolisation or radiotherapy) for either presumed cancer or non-cancerous indications. Complications of treatment occurred in 7 participants (Table S8).

By the 6-month record review, there were 211 (5.3% participants) with serious findings and 1017 (25% participants) with non-serious findings (Figures 1&2). Only 340 (33%) of non-serious findings were referred onwards with 259 (26%) requiring further investigations, the remaining 677 (67%) didn't require further evaluation beyond the YKST scan.

126 participants (3.1% of those scanned) had a serious renal finding (Table 2&S9), the most common being kidney stones >5mm (91 of the 126 findings). Of those, eight required treatment within the follow-up period, the remaining 83 people were observed and provided with kidney stone education.

Figure 3 details 43 renal lesions found in 41 people (1.0% participants), which included: 26 (0.62% participants) solid renal masses or Bosniak 3/4 cysts presumed to be cancer until proven otherwise, 6 benign angiomyolipomas (AML) and 11 Bosniak 2F cysts. 20 (77%) of the solid renal masses/complex cysts were <4cm (cT1a). 10 were subsequently histologically proven to be RCCs (0.25% participants) and five benign oncocytomas (0.12% participants). Nine of the 10 proven RCCs were non-metastatic, seven were <4cm size and seven were low-risk for recurrence by Leibovich score [7]. The remaining nine renal mass/complex cyst patients opted for active surveillance with no biopsy, thus their aetiology is unknown.

There were 917 (23% participants) who had non-serious i.e. incidental renal findings (Table 2&S9), 259 (6.4% participants) requiring further investigations. Benign cysts were the most common finding (n=727, 18% participants). 116 people ultimately diagnosed with renal cysts (16% of those with cysts) required further investigations to determine benignity; 106 had CT (all with preceding renal function blood tests), 7 ultrasound and 1 MRI.

Of the two renal tumours and one Bosniak 2F cyst visible on YLST T2 all were visible on the YLST T0 scan. As such, there was no evidence of incidence of upper pole RCC/lesions developing in the 2-year period between T0 and T2 scans.

The commonest non-renal serious findings were AAAs, being identified in 60 (1.5% participants) (Table 2). Of these, 46 were in the 3-4.4cm annual surveillance range, 11 were in the 4.5-5.4cm 3-monthly imaging category (1 progressed to treatment threshold [>5.4cm] and underwent open AAA repair) and 3 were >5.4cm considered for (and had) urgent surgery (Table S10). 39 (0.97% participants) were in women or men outside the age range for the UK National AAA Screening Programme.

Other serious, non-AAA findings (Tables S11&S12) found only on the abdominal scan included ten confirmed non-renal cancers (0.25% participants), the most common being liver and upper tract urothelial cancers (Table S11 details treatment).

Discussion

YKST is the first prospective study of combined thoracic and abdominal CT screening for lung cancer and serious abdominal conditions in an at-risk population of ever-smokers. YKST shows this combined approach is feasible and acceptable to participants. Uptake was high (93% of eligible attendees), and participants reported high levels of satisfaction. Scan quality was high, with high levels of agreement between radiologists. Scan reporting and actioning of results was timely (median 5 and 8 days respectively). The extra time needed to invite, consent and undertake abdominal NCCT was acceptable (13.3mins). 5.3% participants had a new serious finding only seen on abdominal NCCT, and 0.62% participants immediately benefitted from screening as they were treated with curative intent for a serious finding (including abdominal cancers and AAA). 25% participants had a non-serious finding on abdominal NCCT, although only 6.4% required further investigation(s).

The strength of YKST was utilising an existing targeted screening programme to add an additional screening test. However, as YKST participants were all attending for their second CT thorax 2-years after their first scan, they were likely to be positive about the concept of screening and uptake may be lower when *de novo* participants are invited [16]. Furthermore, by design the study was limited to the entry criteria for YLST, meaning the feasibility and potential impact of screening for younger people <55y or never smokers was not possible.

YKST provides prevalence data to guide the potential impact of such a combined screening approach. A new serious finding was identified in 5.3% participants, including: 0.62% with a solid renal mass or complex cyst (treated as a RCC until proven otherwise), 0.25% with proven non-kidney cancer, 1.5% with AAA and 3.0% other renal findings (mainly renal stones ≥5mm). By comparison, the prevalence of colorectal cancer and high-grade adenomas identified using guaiac-based faecal occult blood tests in the English Bowel Cancer Screening Programme is 0.16% and 0.61% respectively [17]. The UK Breast Cancer Screening Programme breast cancer prevalence is 0.92% [18]. Targeted Lung Health Checks have commenced in the UK with an 1.75% expected prevalence of lung cancers [19]. As such, the prevalence of 0.5% proven cancers in YKST is in the prevalence range of existing UK cancer screening programmes.

As would be hoped for in a screening programme, 77% of the solid renal masses or complex cysts identified in YKST were stage 1 (<4cm size); lesions which are generally curable in 95% cases with surgery or ablation [7].

An unexpected finding was the prevalence of 1.5% for AAAs. This includes an AAA prevalence of 0.67% in women, for whom there is no standalone screening programme for in the UK [6], and AAA prevalence of 1.2% in men out of age-range of the screening invitation at 65y. These individuals benefit both a survival benefit of upto 40% through treatment or surveillance and from provision of secondary prevention of major adverse cardiovascular events and healthy lifestyle advice [6,20,21].

A major workload in YKST was the management of urinary tract stones. 2.2% participants had stones ≥5mm which the UK National Institute for Health and Care Excellence recommend for active treatment due to a 36% greater risk of intervention than stones <5mm [22,23].

A concern with any screening programme is the identification of incidental lesions which do not require treatment but carry the risks associated with diagnosis and treatment, the anxiety associated with these processes, and potential diversion of healthcare resources away from other conditions. In YKST one-quarter of participants had non-serious findings, however only 8.5% required further clinic appointments and 6.4% required investigations. Investigations of incidental findings were limited thanks to robust clinical review and clear lines of communication between the lead-speciality of urology and associated specialities. Reassuringly, in the questionnaire-based YKST 'harms' substudy of 500 participants there were no long-term psychosocial harms to these participants relative to those with a normal scan [24]. Nonetheless, additional workload was generated, given all participants without completely normal abdominal NCCT were discussed in the IRM. This included many participants with confirmed benign renal cysts and small renal stones <5mm, who in future could be sent information sheets and excluded from IRM meeting discussions. Such steps could reduce the proportion of scans needing IRM review from 36% to ~18%.

Of all potential/hypothetical screening modalities for kidney cancer (i.e. urine, blood, ultrasound or abdominal NCCT), the general public are most positive about combined abdominal NCCT and CT thorax [25]. Nonetheless, there is a radiation exposure concern with abdominal NCCT. To mitigate this in YKST the radiation dose of the abdominal NCCT was sequentially reduced to the lowest level (below National reference levels) that still provided high quality interpretable images (by subjective and objective measures). Notably, despite explicitly detailed radiation risks in the participant information sheets, only a minority (7%) of those declining the scan did so due to concerns over the radiation dose.

In conclusion, adding an abdominal NCCT-based screen to the CT thorax within lung cancer screening was feasible and acceptable to participants, with excellent uptake. A cost effectiveness analysis is ongoing. The

number needed to screen to detect one serious abdominal finding was 18, to detect one suspicious renal lesion 93 and one histologically confirmed renal cancer 402, suggesting that further research into screening using abdominal NCCT in combination with thoracic CT is warranted. Future work should focus on screening for serious abdominal abnormalities rather than kidney cancer alone. Prior to clinical implementation studies assessing clinical impact of the diagnoses by measuring disease stage-shift or improved disease specific survival are needed.

Author contributions

GDS and JAU conceptualised the study. GDS, MEJC, JAU, SWB, RDN, SHR, PAJC, TW, AS, GRI, SB and JC designed the study. GDS and JAU sought funding for the study. AG, JK, SWB, CE, NH, CM, SR, IS and MW administered the project. FF, JC, MK, SB, IC, EC, SF, SR, CM, NH, GM, SF, AS and TW collected and provided the data. FF, AG and JK curated the data. GDS, JK, JC, MK and FF accessed and verified the data. GDS, AG, JK, BS, SJS, MEJC and JAU analysed, and interpreted the data. JK, GDS and JAU drafted the manuscript. All authors reviewed and edited the final manuscript. GDS takes overall responsibility for the conduct of the study and all the reported data. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

GDS has received educational grants from Pfizer, AstraZeneca, and Intuitive. Surgical; consultancy fees from Pfizer, Merck, EUSA Pharma, and CMR Surgical; travel expenses from Pfizer; and speaker fees from Pfizer and MSD. GDS is Clinical lead (urology) National Kidney Cancer Audit and Topic Advisor for the NICE kidney cancer guideline. All other authors declare no competing interests.

Data sharing

Individual de-identified participant-level data are available upon request. The YKST trial protocol has been published previously [11].

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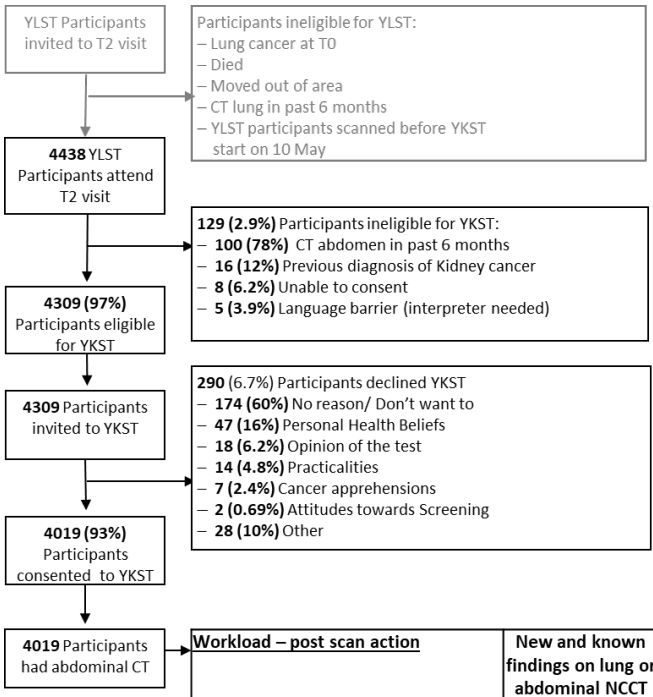
Figures.

Figure 1. YKST CONSORT diagram including details of workload and overview of findings.

[1] 56 participants had >1 new finding, only on abdominal NCCT; [2] 6 participants had >1 new finding, also seen on lung scan; [3]20 participants (0.50%) had >1 Imaging Review Meeting (IRM) referral (17 = 2 referrals, 3 = 3 referrals); [4]16 participants (0.40%) had >1 IRM referral (14 = 2 referrals, 2 = 3 referrals); [5]7 participants referred for known AAA and 22 for adrenal adenomas; [6]3 participants had >1 IRM referral (2 = 2 referrals; 1 = 3 referrals)



Workload – post scan action	New and known findings on lung or abdominal NCCT		New findings on abdominal NCCT only		Known findings on abdominal NCCT only		New findings on lung and abdominal NCCT	
Normal results letter	**2586**	**64%**						
IRM	**1433**[3]	**36%**	**1213**[4]	**30%**	**138**	**3.4%**	**59**[6]	**1.5%**
Letter sent, no further action	787	20%	678	17%	72	1.8%	30	0.75%
Contact with existing clinic	35	0.87%	7	0.17%	23	0.57%	1	0.02%
Referral to new clinic	243	6.0%	181	4.5%	35[5]	0.87%	15	0.37%
Referral to urology clinic	196	4.9%	184	4.6%	7	0.17%	6	0.15%
CT & review in urology MDT	195	4.9%	181	4.5%	1	0.02%	11	0.27%
Number of investigations								
TOTAL	**875**		**723**		115		**37**	
Imaging	360		316		21		23	
Blood tests	468		368		88		12	
Urine tests	41		34		5		2	
Other	6		5		1		-	

Findings - 6-month Outcome Status	New and known findings on lung or abdominal NCCT		New findings on abdominal NCCT only[1]		Known findings on abdominal NCCT only		New findings on lung and abdominal NCCT[2]	
Serious finding(s)	289	7.2%	211	5.3%	55	1.4%	15	0.37%
Confirmed RCC	*12*	*0.29%*	*10*	*0.25%*	-	-	2	0.05%
Confirmed other cancer	*15*	*0.37%*	*10*	*0.25%*	-	-	5	0.12%
Non-serious finding(s)	1169	29%	1017	25%	87	2.2%	48	1.2%
Benign cysts/ Bosniak 1 or 2	*796*	*20%*	*727*	*18%*	30	0.75%	37	0.92%

Figure 2. Summary of prevalence of findings.

Amongst the non-serious findings, 15 participants had both new serious and new non-serious findings (0.37%). 14 (0.35%) had an investigation, 5 just for the serious finding, 1 for the non-serious finding and 8 for all the findings. Denominator: all scanned n=4019.

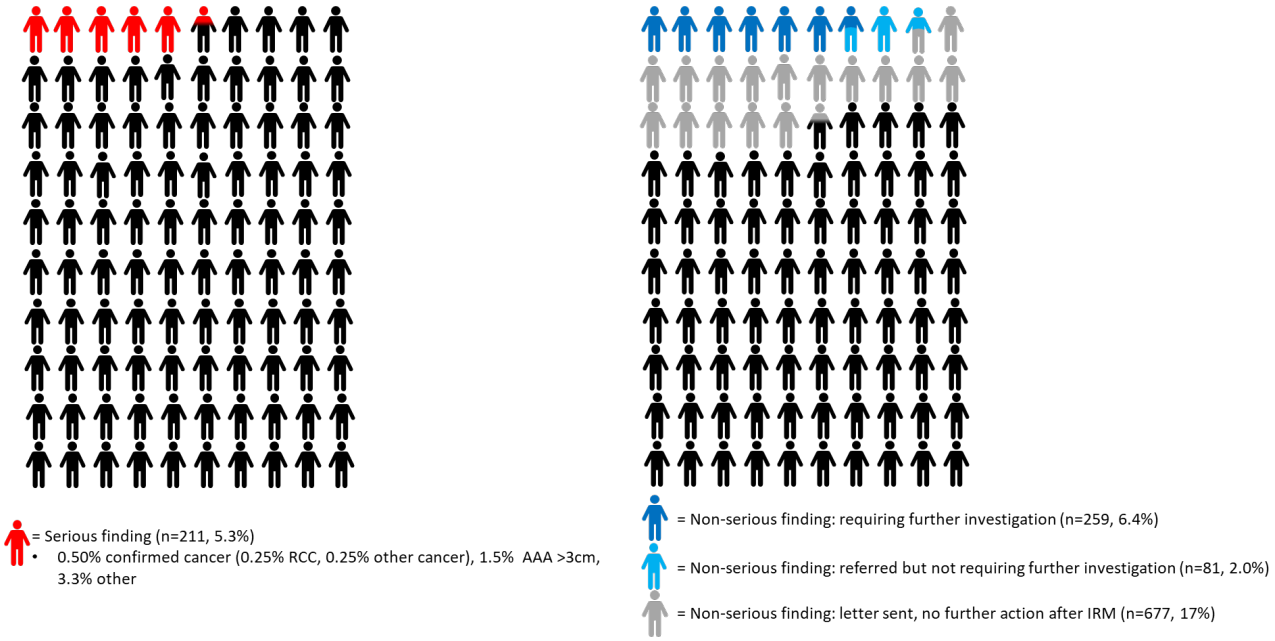
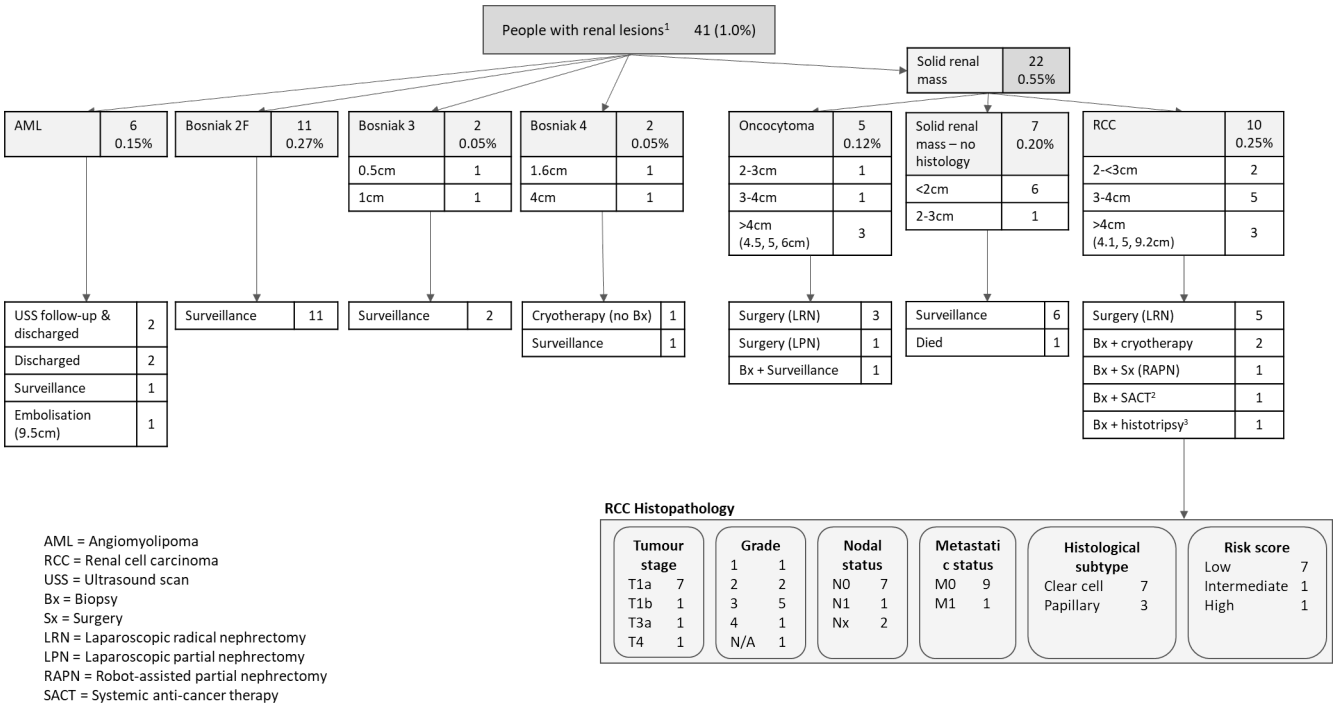


Figure 3. Details of new renal lesions found only on the abdominal NCCT scan.

Bosniak classification: a measure of the level of complexity of a renal cyst and reflects the likelihood of it harboring malignancy. IMDC = International Metastatic RCC Database Consortium. [1]2 people had 2 suspicious renal lesions: 1 renal mass + Bosniak 2F; 1 renal mass + Bosniak 4. [2]IMDC intermediate risk mRCC. [3]Histotripsy for a cT1a RCC, within the CAIN trial. Denominator: all scanned n=4019.



AML = Angiomyolipoma
RCC = Renal cell carcinoma
USS = Ultrasound scan
Bx = Biopsy
Sx = Surgery
LRN = Laparoscopic radical nephrectomy
LPN = Laparoscopic partial nephrectomy
RAPN = Robot-assisted partial nephrectomy
SACT = Systemic anti-cancer therapy

Table 1. Details of reasons for declining abdominal NCCT.
Denominator: All providing a reason for declining kidney scan (n=116)

Reasons for declining kidney scan *Excludes 'no reason' or 'don't want to'*	**TOTAL 116**		**Examples of reasons**
Personal health beliefs	**47**	41%	
Believes kidneys are already being monitored	26	22%	*"Already had some kidney tests done"* *"Already under kidney specialists"* *"Recently had kidney test, don't need a scan."* *"Has had recent Investigations – feels happy all ok."* *"Had a recent blood test & kidneys are OK."* *"Had blood tests done recently and that would have picked anything up."*
Perceives kidneys to be okay	3	2.6%	*"No problems with kidneys, so not bothered about having it"*
Too many health issues	9	7.8%	*"Already having other investigations."* *"I have other health issues to contend with at the moment"*
Because of my age/ too old	7	6.0%	*"Don't see the point because of my age"* *"I feel too old now. I would have done when younger."* *"I feel that aged 79, I'm unlikely to receive any attention."*
Other – Personal health beliefs	2	1.7%	*"I'm not sure of the date of my last kidney scan"*
Opinions of the test	**18**	16%	
Claustrophobic	8	6.9%	*"The shorter time I am on the scanner the better."* *"Anxiety towards confined spaces"*
Radiation concerns	8	6.9%	*"I don't want to be exposed to additional radiation"*
Other – Opinions of the test	2	1.7%	*"I had a scan last year. I don't want an extra CT scan."* *"I am worried about lying down for long periods of time due to mucus in my lungs." (82 year old)*
Practicalities	**14**	12%	
Too busy/ not enough time	10	8.6%	*"I don't have any time today."*
Other – Practicalities	4	3.4%	*"Blind"* *"Too much of an effort."*
Cancer apprehension	**7**	6.0%	*"I'd rather not at this time. I am anxious about the lung check already"* *"It's too stressful waiting for the results"*
Attitudes towards screening	**2**	1.7%	*"I don't want to see into the future."*
Other	**28**	24%	
Maybe in the future/ need more time to think about it	11	9.5%	*"I would prefer time to consider this and discuss with my husband and family"* *"I want to think about it a bit more."*
Too much going on	4	3.4%	*"There is too much going on at the moment."*
Has CT scan booked	4	3.4%	*"I have a CT scan planned."*
Other – Other	9	7.8%	*"I'm worried about travel insurance."* *"I have memory problems and I am worried about my ability to consent."* *"I want to drop out of the research after today."*

Table 2. Categories of serious and non-serious findings.

Denominator: All scanned n=4019; [1]4 people had 2 serious renal findings, including 1 with known single kidney + stones ≥5mm; [2]3 people had 2 new serious renal findings; [3]3 people had 2 new serious renal findings on abdominal NCCT only; [4]30 people had 2 non-serious renal findings + 1 had 3 non-serious renal findings; [5]29 people had 2 new non-serious renal findings; [6]28 people had 2 new non-serious renal findings on abdominal NCCT only.

	Serious Findings			**Non-serious Findings**		
Findings by organ Number of people	**New and known findings on lung or abdominal NCCT**	**New findings on lung or abdominal NCCT**	**New findings on abdominal NCCT only**	**New and known findings on lung or abdominal NCCT**	**New findings on lung or abdominal NCCT**	**New findings on abdominal NCCT only**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Kidney	156[1] (3.9)	134[2] (3.3)	126[3] (3.1)	994[4](25)	957[5] (24)	917[6](23)
Vascular (all AAAs)	94 (2.3)	62 (1.5)	60 (1.5)	1 (0.02)	0	0
Liver	8 (0.20)	4 (0.10)	3 (0.07)	17 (0.42)	16 (0.40)	15 (0.37)
Adrenal	7 (0.17)	3 (0.07)	2 (0.05)	110 (2.7)	49 (1.2)	43 (1.1)
Spine (all fractures)	6 (0.15)	6 (0.15)	5 (0.12)	0	0	0
Pancreas	4 (0.10)	4 (0.10)	3 (0.07)	30 (0.75)	28 (0.70)	28 (0.70)
Bladder	4 (0.10)	2 (0.05)	2 (0.05)	0	0	0
Gallbladder/ Biliary	3 (0.07)	3 (0.07)	3 (0.07)	13 (0.32)	13 (0.32)	13 (0.32)
Spleen	1 (0.02)	1 (0.02)	1 (0.02)	5 (0.12)	1 (0.02)	1 (0.02)
Bowel	1 (0.02)	1 (0.02)	1 (0.02)	5 (0.12)	4 (0.10)	3 (0.07)
Other	12 (0.30)	11 (0.27)	7 (0.17)	8 (0.20)	7 (0.17)	7 (0.17)
≥1 finding	**290 (7.2)**	**226 (5.6)**	**211 (5.3)**	**1168 (29)**	**1065 (27)**	**1017 (25)**

Abdominal non-contrast CT scanning to screen for kidney cancer and other abdominal pathology within community-based CT screening for lung cancer

Supplementary material

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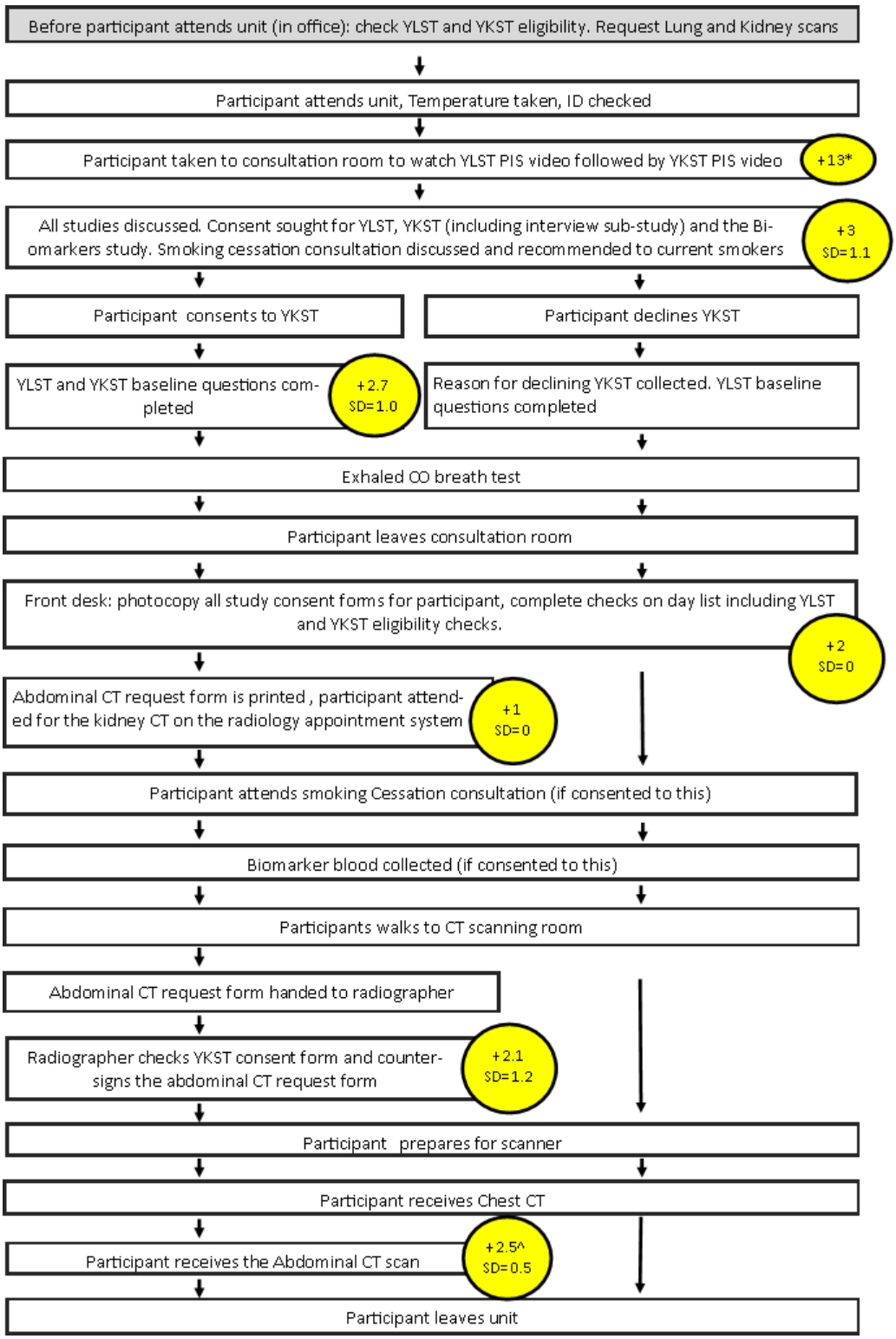
Supplementary figures

Figure S1. Flow diagram of each stage of the combined screening approach and the additional time required for each of YKST specific process (yellow ovals, n=8 participants assessed).

*not involving unit staff; ^Some patients need slight repositioning between scans (additional 1-2 mins).



Supplementary tables

Table S1. Definitions of serious and non-serious abdominal findings, taken from [15] and expert opinion.

Finding category	Serious	Non-serious
Vascular		
Abdominal aortic aneurysm (≥3cm)	All	
Aortic dissection	All	
Visceral artery aneurysm	All	
Pancreas		
Acute pancreatitis	All	
Chronic pancreatitis		All
Pancreatic adenocarcinoma (inc. ampullary cancer)	All	
Pancreas NET	All	
Main Duct IPMN	All	
Side Branch IPMN	All	
Pancreatic cysts	Mucinous cystic neoplasm	Serous cystic neoplasm Simple cyst
Stomach		
Mass/thickening	All	
Oesophagus		
Mass/thickening	All	
Adrenal glands		
Adrenal adenoma/mass	HU ≥10 and/or size ≥4cm All functioning adenomas Heterogenous lesion Adrenal cancer or metastatic disease	Size<1cm HU ≤10 Homogeneous lesion
Adrenal cyst	Any solid component treat as adrenal adenoma/mass	Simple cyst
Gallbladder/biliary		
Gallbladder cancer	All	
Gallbladder polyp	Solitary > 0.5cm (0.5-1 surveillance, surgery for >1cm (possibly smaller for Asian populations)	Multiple cysts
Gallstones in gallbladder		All
Gallstones in CBD	All (recommend ERCP)	
Porcelain gallbladder		Used to recommend surgery. Modern literature suggests cancer risk negligible.
Extra hepatic Cholangiocarcinoma	All	
Liver		
Fatty liver		All
Cirrhosis	All	
Haemangioma		All
Liver cyst	Size ≥ 4cm Loculated/septated	Simple cyst < 4 cm

	Any solid component (treat as adenoma or adenocarcinoma)	
Adenoma	All	
Focal Nodular Hyperplasia		All
Metastases (inc adenocarcinoma)	All	
Cholangiocarcinoma	All	
Hepatocellular Carcinoma	All	
Kidneys		
Renal mass [assume a solid mass that is not biopsied]	All	
Renal oncocytoma		All
Renal cyst	Bosniak 2F, 3, 4 cysts	Bosniak 1, 2 cysts
Renal stone	≥5mm single stone or multiple stones collectively ≥5mm or any stone related hydronephrosis or <5mm and single kidney	<5mm
Ureteric stone	≥3mm or any stone related hydronephrosis, or <3mm and single kidney	<3mm
Single kidney / horseshoe kidney / duplex system / pelvic kidney		All
Renal cancer	All	
Collecting system cancer	All	
Angiomyolipoma	≥4cm	<4cm
Spleen		
Splenomegaly	≥15cm	
Solid splenic lesion	All	
Cystic splenic lesion		All (simple cyst)
Other		
Lymphadenopathy	≥1cm or multiple	Solitary <1cm
Ascites	All	
Metastatic cancer	All	
Duodenal cancer	All	

Table S2. Demographics of YKST participants.

*p>0.10, **p<0.10, ***p<0.05, ****p<0.01, ****p<0.01, *****OR for age estimated for 10-year difference in age, p<0.001. OR-odds ratio; SD-standard deviation; CI-confidence interval.

	Consented to YKST		**Declined YKST**		**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Number of individuals	**4019**		**290**			
Age (years)					0.65 (0.55 - 0.78)*****	0.55 (0.45 - 0.66)*****
Mean (SD)	68	(6.9)	70	(7.3)		
55-64	1290	32%	70	24%		
65-74	1898	47%	122	42%		
≥75	831	21%	98	34%		
Sex						
Male	2241	56%	143	49%	Ref	Ref
Female	1778	44%	147	51%	0.77 (0.61 - 0.98)***	0.76 (0.60 - 0.97)***
Smoking Status						
Ex-Smoker	2793	70%	186	64%	Ref	Ref
Current Smoker	1226	31%	104	36%	0.79 (0.61 - 1.01)**	0.67 (0.51 - 0.87)***
Ethnicity						
White	3881	97%	279	96%	Ref	Ref
Asian	47	1.2%	6	2.1%	0.92 (0.50 - 1.89)*	0.88 (0.47 - 1.82)*
Black	34	0.85%	2	0.7%		
Hispanic	1	0.02%	0	0.0%		
Other	46	1.1%	2	0.7%		
Prefer not to say	10	0.25%	1	0.3%		
Index of Multiple Deprivation (IMD)						
Median (IQR)	5	(2 - 7)	4	(2 - 7)		
1st Quintile	1107	28%	103	36%	0.80 (0.55 - 1.1)*	0.72 (0.50- 1.02)**
2nd Quintile	716	18%	59	20%	0.88 (0.60 - 1.30)*	0.83 (0.56 - 1.22)*
3rd Quintile	717	18%	52	18%	Ref	Ref
4th Quintile	912	23%	49	17%	1.35 (0.90 - 2.02)*	1.38 (0.92 - 2.08)*
5th Quintile	567	14%	27	9.3%	1.52 (0.95 - 2.50)*	1.54 (0.96 - 2.52)**
Body Mass Index (BMI)						
Mean (SD)	29	(5.3)	28	(5.2)		
<20	97	2.4%	15	5.2%		
20-<25	855	21	74	26%		
≥25	3066	76%	201	69%		
Missing	1	0.02%	0	-		
Diabetes						
Yes (any type)	678	17%	-	-		
High Blood Pressure						

Yes	1693	42%	-	-		
On Medication for High Blood Pressure						
Yes	1613	40%	-	-		
Family history of kidney cancer						
Yes	91	2.3%	-	-		
Family history of pancreatic cancer						
Yes	139	3.5%	-	-		
Alcohol units consumed in an average week						
Mean (SD)	13.8	(20)	-	-		
Median (IQR)	6	(0 - 20)	-	-		
None	1344	33%	-	-		
0.5-14 units	1342	33%	-	-		
>14 units	1329	33%	-	-		
Missing	4	0.10%	-	-		

Table S3. Questionnaire response data for participants with a normal CT, abnormal CT requiring no further action, abnormal CT requiring further action and all respondents weighted based on the scan results within the entire cohort.

* = Very satisfied or satisfied (Full scale: Very satisfied; Satisfied; Neither satisfied nor dissatisfied; Dissatisfied; Very dissatisfied); ** = Yes definitely or yes probably (Full scale: Yes definitely; Yes probably; I don't know; No not really; No not at all); *** = Strongly agree or agree (Full scale: Strongly agree; Agree; Neither disagree nor agree; Disagree; Strongly disagree)

	Normal scan		**Abnormal scan – no further action**		**Abnormal scan – further action**		**Percentage weighted for distribution of scan results in the whole cohort**
	Total n for question	**n (%)**	**Total n for question**	**n (%)**	**Total n for question**	**n (%)**	
Satisfied* with information	154	144 (94)	129	120 (93)	96	90 (94)	93
Satisfied* with communication of results	149	146 (98)	128	123 (96)	95	85 (89)	96
Regretted decision to have the scan**	133	4 (3.0)	106	4 (3.8)	86	7 (8.1)	3.9
Sufficient time**	154	153 (99)	128	126 (98)	96	90 (94)	98
Right decision to participate***	153	148 (97)	124	121 (98)	95	94 (99)	97

Table S4. Abdominal NCCT scan dose and quality. CTDIvol = CT dose index volume; ROI = Region of interest; KUB = Kidneys, ureter and bladder.

[1] Data missing for 176 participants; [2] Data missing for 61 participants.

	Initial protocol	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Final iteration
Number of participants	141	106	322	223	1286	1941
Start Date	10/05/2021	18/05/2021	08/06/2021	12/07/2021	09/08/2021	11/01/2022
Average CTDIvol (mGy)[1]	11.8	10.3	8.3	6.6	5.9	4.8
Median CTDIvol (mGy) [1]	12.2	9.7	6.8	5.5	5.0	4.0
Average E (mSv) [2]	4.8	4.3	3.0	2.8	2.5	2.0
Qualitative assessment 20 scans per iteration						
1 (Poor)	0	0	0	0	0	0
2 (Fair)	2	0	0	0	0	0
3 (Good)	3	0	1	1	1	1
4 (Very good)	2	7	6	6	6	8
5 (Excellent)	13	13	13	13	13	11
Median overall Likert score (IQR)	5 (3.5-5)	5 (4-5)	5 (4-5)	5 (4-5)	5 (4-5)	5 (4-5)
Quantitative assessment						
SD of the ROI (Hounsfield units)	14.1	15.0	15.2	16.4	15.9	15.3

	CTDIvol exceeds National Diagnostic Reference Level for KUB examinations (10mGy)
	CTDIvol exceeds Local Diagnostic Reference Level for KUB examinations (5.3mGy)

Table S5. Proportion of scans identified for 5 YKST abdominal NCCT reporting categories.

Denominator: Total number of scans read

	TOTAL	**Radiologist X**	**Radiologist Y**	**Radiologist Z**
	n (%)	**n (%)**	**n (%)**	**n (%)**
YKST 1 Normal	2588 (64)	669 (71)	1611 (64)	315 (56)
YKST 2 Benign urological finding	944 (24)	198 (21)	562 (22)	164 (29)
YKST 3 Indeterminate benign finding	309 (7.7)	62 (6.5)	192 (7.7)	44 (7.8)
YKST 4 Possible AAA or malignancy outside renal tract	23 (0.6)	1 (0.1)	19 (0.8)	8 (1.4)
YKST 5 Possible renal/urological cancer	155 (3.9)	19 (2.0)	125 (5.0)	30 (5.3)
Total number of scans read	**4019**	**949**	**2509**	**561**

Table S6. Total number of people having investigations and procedures/ treatments following findings on the abdominal NCCT scan. Where an individual had more than 1 finding, the investigation, procedure or treatments have been apportioned to the serious finding(s).

[1]17 people with a serious finding only seen on abdominal NCCT scan who needed an investigation had >1 finding and 6 people who needed a procedure. Denominator: all people scanned n=4019.

Number of people	**New and known findings on lung or abdominal NCCT**		**New finding on abdominal NCCT scan only**		**New serious findings on abdominal NCCT scan only[1]**		**New non serious findings on abdominal NCCT scan only**	
Investigations								
Blood tests	392	9.8%	328	8.2%	100	2.5%	228	5.7%
Any imaging	310	7.7%	272	6.8%	90	2.2%	182	4.5%
CT	233	5.8%	209	5.2%	57	1.4%	152	3.8%
Ultrasound	60	1.5%	50	1.2%	27	0.67%	23	0.57%
Nuclear medicine tests	18	0.45%	13	0.32%	9	0.22%	4	0.10%
MRI	17	0.42%	16	0.40%	10	0.25%	6	0.15%
Specialist USS	11	0.27%	11	0.27%	2	0.05%	9	0.22%
X-ray	3	0.07%	3	0.07%	2	0.05%	1	0.02%
Fluoroscopy	1	0.02%						
Urine tests	38	0.95%	19	0.47%	5	0.12%	14	0.35%
Other investigations	5	0.12%	4	0.10%	3	0.07%	1	0.02%
Number of people ≥1 investigation	**445**	**11%**	**370**	**9.2%**	**124**	**3.1%**	**246**	**6.1%**
Procedures/treatments								
Surgery	23	0.57%	18	0.45%	14	0.35%	4	0.10%
Percutaneous Biopsy	16	0.40%	12	0.30%	10	0.25%	2	0.05%
Endoscopy	14	0.35%	11	0.27%	7	0.17%	4	0.10%
Cystoscopy	*5*	*0.12%*	*3*	*0.07%*	*3*	*0.07%*		
ERCP	*3*	*0.07%*	*3*	*0.07%*	*1*	*0.02%*	2	0.05%
Endoscopy	*2*	*0.05%*	*2*	*0.05%*	*2*	*0.05%*		
Ureteroscopy	*2*	*0.05%*	*1*	*0.02%*	*1*	*0.02%*		
Colonoscopy	*1*	*0.02%*						
Gastroscopy	*1*	*0.02%*						
Lithotripsy	9	0.22%	7	0.17%	7	0.17%		
Systemic anti-cancer therapy	6	0.15%	3	0.07%	3	0.07%		
Ureteric Stent	4	0.10%	2	0.05%	2	0.05%		
Thermal Ablation	4	0.10%	4	0.10%	4	0.10%		
Radiotherapy	1	0.02%	1	0.02%	1	0.02%		
Embolisation	1	0.02%	1	0.02%	1	0.02%		
Number of people ≥1 procedure/ treatment	**62**	**1.5%**	**52**	**1.3%**	**40**	**1.0%**	**12**	**0.30%**

Table S7. Total number of investigations, procedures and treatments triggered by YKST. Where there was more than 1 finding, the investigation, procedure or treatments have been apportioned to the serious finding(s).

Number of investigations/ procedures/ treatments	**New and known findings on lung or abdominal NCCT**		**New finding on abdominal NCCT scan only**		**New serious findings on abdominal NCCT scan only**		**New non-serious findings on abdominal NCCT scan only**	
Investigations *Denominator: Total number of investigations*								
Blood tests	468	54%	368	51%	113	47%	254	53%
Imaging	360	41%	316	44%	116	49%	198	41%
CT	*244*	*28%*	*219*	*30%*	*63*	26%	*154*	32%
Ultrasound	*62*	*7.1%*	*51*	*7.1%*	*27*	11%	*24*	5.0%
MRI	*20*	*2.3%*	*19*	*2.6%*	*13*	5.4%	*6*	1.2%
Nuclear medicine tests	*18*	*2.1%*	*13*	*1.8%*	*9*	3.8%	*4*	0.83%
Specialist USS	*11*	*1.3%*	*11*	*1.5%*	*2*	0.84%	*9*	1.9%
X-ray	*3*	*0.3%*	*3*	*0.4%*	*2*	0.84%	*1*	0.21%
Fluoroscopy	*2*	*0.2%*						
Urine tests	41	4.7%	34	4.7%	6	2.5%	28	5.8%
Other investigations	6	0.7%	5	0.7%	4	1.7%	1	0.21%
Total number of investigations	**875**		**723**		**239**		**481**	
Procedures/treatments *Denominator: Total number of procedures/ treatments*								
Surgery	23	26%	18	29%	14	26%	4	0.10%
Endoscopy	16	18%	10	16%	7	13%	3	0.07%
Cystoscopy	*6*	*6.9%*	*3*	*4.8%*	*3*	*5.6%*		
ERCP	*4*	*4.6%*	*4*	*6.4%*	*1*	*1.9%*	3	0.07%
Endoscopy	*2*	*2.3%*	*2*	*3.2%*	*2*	*3.7%*		
Ureteroscopy	*2*	*2.3%*	*1*	*1.6%*	*1*	*1.9%*		
Colonoscopy	*1*	*1.2%*						
Gastroscopy	*1*	*1.2%*						
Lithotripsy	16	18%	12	19%	12	22%		
Percutaneous Biopsy	16	18%	12	19%	10	19%	2	0.05%
SACT	6	6.9%	3	4.8%	3	5.6%		
Ureteric Stent	4	4.6%	2	3.2%	2	3.7%		
Thermal Ablation	4	4.6%	4	6.4%	4	7.4%		
Radiotherapy	1	1.2%	1	1.6%	1	1.9%		
Embolisation	1	1.2%	1	1.6%	1	1.9%		
Total number of procedures/ treatments	**87**		**63**		**54**		**9**	

Table S8. Complications from interventions occurring by the point of the 6 month review.

YKST category	Complication	Clavien-Dindo classification if following a procedure	Details
YKST 4	Post-EUS pancreatitis	Grade II	Pancreatitis following EUS for lymph node biopsy. Enteral feeding and treatment for diabetic provided. Patient recovered but with development of diabetes.
YKST 3	Post-ERCP cholangitis	Grade II	Treated with IV fluids, IV antibiotics and analgesia. Patient fully recovered.
YKST 5	Post-operative bleed & acute kidney injury	Grade II	Treated with a 3 unit blood transfusion, IV fluids, IV antibiotics and an enema for constipation. Patient fully recovered.
YKST 5	Post-operative renal failure & metabolic acidosis	Grade IVa	3 day ICU admission for haemofiltration following AAA repair. Renal function recovered to pre-operative level.
YKST 5	Coffee ground vomiting	Grade II	Coffee ground vomit. Unable to tolerate upper GI endoscopy. Barium swallow showed dysphagia due to mild dysmotility and mild gastric reflux. No further episodes of coffee ground vomit and patient discharged from gastroenterology follow up.
YKST 5	Post-surgical wound infection & collection	Grade II	Treated with with flucloxacillin, district nurse support for dressings. Patient fully recovered.
YKST 5	Post-operative haemorrhage	Grade II	Flank bruising and drop in haemoglobin. CT showed haematoma. Blood transfusion of 2 units. Patient fully recovered.
YKST 5	Post-operative superficial wound breakdown	Grade II	Treated with IV antibiotics. Patient fully recovered.

Table S9. Serious and non-serious renal findings by diagnosis.

Denominator: all scanned n=4019

Serious renal findings Number of people	**New and known findings on lung or abdominal NCCT scan**		**New finding on lung or abdominal NCCT scan**		**New finding, on abdominal NCCT scan only**	
Kidney stone ≥5mm	110	2.7%	95	2.4%	91	2.3%
Bosniak cyst 2F, 3 or 4	17	0.42%	15	0.37%	15	0.37%
Renal cancer – histologically proven	12	0.30%	12	0.30%	10	0.25%
Pelviureteric junction obstruction	8	0.20%	3	0.07%	2	0.05%
Renal mass – no histology	7	0.17%	7	0.17%	7	0.17%
Renal angiomyolipoma ≥4cm	1	0.02%	1	0.02%	1	0.02%
Polycystic kidney disease – with CKD4	1	0.02%	1	0.02%	1	0.02%
Vesicoureteric junction stricture	2	0.05%	2	0.05%	2	0.05%
Staghorn kidney stone	1	0.02%	1	0.02%	0	0%
Single kidney with stones	1	0.02%	0	0%	0	0%
≥1 serious renal finding	**156**	**3.9%**	**134**	**3.3%**	**126**	**3.1%**
Non-serious renal findings Number of people	**New and known findings on lung or abdominal NCCT scan**		**New finding on lung or abdominal NCCT scan**		**New finding on abdominal NCCT scan only**	
Benign cyst/Bosniak 1 or 2	796	20%	764	19%	727	18%
Kidney stone <5mm	123	3.1%	119	3.0%	118	2.9%
Other renal anatomical variant	32	0.80%	32	0.80%	32	0.80%
Atrophic kidney	27	0.67%	27	0.67%	25	0.62%
Single kidney	12	0.30%	12	0.30%	12	0.30%
Other benign urology	12	0.30%	11	0.27%	11	0.27%
AML <4cm	7	0.17%	5	0.12%	5	0.12%
Renal calcification	5	0.12%	5	0.12%	5	0.12%
Oncocytoma	5	0.12%	5	0.12%	5	0.12%
Pelviureteric junction obstruction appearance – non-obstructed	4	0.10%	4	0.10%	3	0.07%
Renal artery aneurysm	3	0.07%	3	0.07%	2	0.05%
Polycystic kidney disease – no sequalae	1	0.02%	1	0.02%	1	0.02%
≥1 non-serious renal finding	**994**	**25%**	**957**	**24%**	**917**	**23%**

Table S10. Details of AAAs detected.

Denominator: total number of AAAs

Already registered on NAAASP[1]	**33**			
	All new AAAs, on lung or abdominal NCCT scan		**New AAAs, on abdominal NCCT scan only**	
Total number of people	**62**		**60**	
	n	**%**	**n**	**%**
New diagnosis by size				
3-4.4cm (recommended annual ultrasound)	48	77%	46	77%
4.5-5.4cm (recommended 3-monthly ultrasound) [2]	11	18%	11	18%
5.5cm+ (referred for consideration of surgery) [3]	3	4.8%	3	5.0%
New diagnosis by age and gender				
Female	**12**	**19%**	**12**	**20%**
55-64	1	8.3%	1	8.3%
65-74	7	58%	7	58%
75+	4	33%	4	33%
Male	**50**	**81%**	**48**	**80%**
55-64	11	22%	10	21%
65-74	22	44%	21	44%
75+	17	34%	17	35%

[1]1 known AAA had increased in size (to 5.6cm); underwent percutaneous endovascular aneurysm repair (EVAR)
[2]1 open AAA repair (5.4cm on initial scan, subsequent growth to >5.5cm on surveillance USS)
[3]2 open AAA repair (6.3cm & 6cm)
1 Fenestrated EVAR (7.2 cm)

Table S11. Detailed information on all proven cancers. RCC = Renal cell carcinoma; UUTUCC = Upper urinary tract urothelial cell carcinoma; SACT = Systemic anti-cancer therapy; SCC = Squamous cell carcinoma; Pancreatic NET = Pancreatic neuroendocrine tumour; SACT = Systemic anti-cancer therapy

Confirmed cancer findings	Tumour size	Tumour stage	Grade	Nodal status	Metastatic status	Histological subtype	Risk score	Treatment
RCC	20mm	T1a	2	N0	M0	Papillary	Low	Thermal ablation
Oncocytic papillary RCC	33mm	T1a	N/A	N0	M0	Papillary	Low	Thermal ablation
RCC	36mm	T1a	3	N0	M0	Clear cell	Low	Surgery
RCC	32mm	T1a	2 & 3	NX	M0	Papillary	Low	Surgery
RCC	35mm	T1a	3	N0	M0	Clear cell	Low	Surgery
RCC	41mm	T1a	3	N0	M0	Clear cell	Intermediate	Surgery
RCC	30mm	T1a	3	N0	M0	Clear cell	Low	Surgery
RCC	50mm	T3a	4	NX	M0	Clear cell	High	Surgery
RCC	25mm	T1a	1	NO	M0	Clear cell	Low	Thermal ablation
Metastatic RCC	92mm	T4	2	N1	M1	Clear cell	IMDC intermediate risk mRCC	Palliative SACT
Liver (likely cholangiocarcinoma)	150mm	Stage 4	N/A	N1	M1	Poorly differentiated adenocarcinoma, likely cholangiocarcinoma	-	Palliative SACT
Liver (hepatocellular carcinoma)	42mm	T1b	N/A	N0	M0	Hepatocellular carcinoma	-	Radiotherapy /Died
Bowel (multicystic mesothelioma)	2 bowel polyps & peritoneal deposits	N/A	N/A	N0	M0	Multicystic mesothelioma	-	Surgery
Distal ureteric UUTUCC	23mm	T1	G2 (HG)	N0	M0	Urothelial carcinoma	-	Surgery
Renal pelvis and proximal ureteric UUTUCC (known bladder cancer G2pTa)	75mm	pT3a	3	Nx	M0	High grade urothelial carcinoma	-	Surgery
Metastatic carcinoma	Patient died before primary confirmed						-	Died
Oesophageal SCC	27mm	T3		N2	M0	SCC	-	Palliative SACT
Mantle cell lymphoma		Stage 4					-	Surveillance
Hodgkin lymphoma		Stage 1					-	Surveillance
Pancreatic NET	11mm						-	Surveillance

Table S12. Details of non-renal, non-AAA serious findings.

	New finding on lung or abdominal NCCT scan	New finding on abdominal NCCT scan only
Spine		
Fractures	6	5
Liver		
Cirrhosis	2	1
Hepatocellular carcinoma	1	1
Metastases inc. adenocarcinoma	1	1
Pancreas		
Pancreas IPMN (intraductal papillary mucinous neoplasm)	2	2
Pancreatic adenocarcinoma	1	0
Pancreatic NET (neuroendocrine tumour)	1	1
Adrenal		
Adrenal adenoma	3	2
Ureter		
Distal ureteric UUTUCC (upper urinary tract urothelial cell carcinoma)	2	2
Congenital mega ureter	1	0
Gallbladder		
Gallstones in common bile duct	1	1
Bile stone disease	1	1
Cholecystitis	1	1
Bladder		
Bladder outlet obstruction due to benign prostatic enlargement	2	1
Spleen		
Splenomegaly ≥15cm	1	1
Bowel		
Bowel cancer	1	1
Other cancers		
Adenocarcinoma of fallopian tube	1	0
Follicular lymphoma	1	0
Metastatic carcinoma of unknown primary	1	1
Oesophageal squamous cell carcinoma	1	1
Metastatic neuroendocrine tumour	1	0
Mantle cell lymphoma	1	1
Hodgkin lymphoma	1	1
Metastatic lung cancer	1	0
Total number of people with ≥1 non-renal, non-AAA serious finding	**32 (0.80%)**	**25 (0.62%)**

Table S13. Details of non-serious non-renal findings.

Denominator: all scanned n=4019.

	New finding on lung or abdominal NCCT scan		New finding on abdominal NCCT scan only	
Adrenal				
Adrenal adenoma	49	1.2%	43	1.1%
Pancreas				
Chronic pancreatitis	13	0.32%	13	0.32%
Benign pancreatic cyst or lesion	11	0.27%	11	0.27%
Other non-serious pancreas	4	0.10%	4	0.10%
Liver				
Fatty liver	8	0.20%	7	0.17%
Benign liver cyst	4	0.10%	4	0.10%
Haemangioma	3	0.07%	3	0.07%
Benign liver lesion	1	0.02%	1	0.02%
Chronic liver disease	1	0.02%	1	0.02%
Gallbladder				
Gallstones	9	0.22%	9	0.22%
Porcelain gall bladder	2	0.05%	2	0.05%
Other non-serious gallbladder	2	0.05%	2	0.05%
Bowel				
Diverticulosis	3	0.07%	3	0.07%
Benign polyps	1	0.02%	0	0.00%
Spleen				
Simple cyst	1	0.02%	1	0.02%
Other	5	0.12%	5	0.12%
Total number of people with ≥1 non-renal, non-AAA, non-serious finding	**112**	**2.8%**	**103**	**2.6%**

Supplementary text

Supplementary methods

Detailed description of exclusion criteria

Being on palliative care was defined as being on the palliative care register (Gold Standards Framework). Dementia was defined as having a primary care coded diagnosis of dementia. Frailty was defined as a GP coded diagnosis of 'severe frailty' or recorded Electronic Frailty Index >0.36. Nursing home residents or GP coded status of 'Housebound' was used to define nursing home or housebound exclusion criteria.

Detailed procedures

The YLST team telephoned participants who were due their T2 visit to arrange an appointment date and sent appointment letters out. These participants were screened for YKST eligibility, ahead of their visit to the YLST mobile unit. When those participants who were eligible for YKST attended their T2 YLST visit they were shown the YKST participant information video and invited to participate. All those who declined were invited to provide a brief reason. Participants were recruited between 10th May 2021-26th October 2022.
Consenting participants had the abdominal NCCT scan during their T2 YLST visit. The scan, from the diaphragm to the bottom of the kidneys, was obtained separately from the CT thorax. Radiation exposure was iteratively reduced throughout YKST. Scan quality was assessed subjectively by an independent consultant uro-radiologist (IC) using a Likert score (1-5, low to high quality) who reviewed 20 scans from each dose iteration and objectively for a random sample of 10% of normal scans using the standard deviation (SD) of a 1-3cm region of interest (ROI) in paraspinal fat. Quality assurance of scan reporting was undertaken by performing a double-read of the same 10% of the normal scans. Each element of the combined screening was timed on one day by one member of the research team (AG).
Scans were reported by one of three consultant uro-radiologists. The abdominal NCCT scans were coded as follows:

- YKST1: normal
- YKST2: benign renal finding
- YKST3: benign non-renal finding (e.g. cholecystitis/pancreatitis) or abdominal aortic aneurysms (AAA) <5cm

- YKST4: possible non-renal malignancy or ≥5cm AAA
- YKST5: possible renal malignancy

A twice-weekly Imaging Review Meeting (IRM) was run by a consultant urologist (JC or MK), clinical nurse specialist (FF) and administrative assistant. YKST 1 participants were automatically sent 'normal scan' letters and not routinely reviewed in the IRM. YKST 2-5 participants were all reviewed in IRM and one-of-five triaging options applied: letter of reassurance for benign findings requiring no further action, reconnect with a clinic for a known problem, referral to a new non-urology clinic, referral to a urology clinic or referral for a CT scan with MDT review. Henceforth, patients were managed as per standard-of-care by the appropriate specialty team.

Review of the electronic health record of any participant with an abnormal abdominal NCCT scan was undertaken 6-months after the scan, findings were categorised into serious or non-serious based on the final diagnosis. Serious findings were defined as those that carry a real prospect of seriously threatening life span, or of having a substantial impact on major body functions or quality of life based on previous published recommendations, clinical expert recommendations and national guidelines (Table S1) [15].

Adverse events were collected between the time participants entered the mobile unit and when their result letter was written to them. The Clavien-Dindo system was used to grade any complications related to investigations or surgical treatments [26].

Analysis the reasons for declining the abdominal NCCT

To analysis the reasons for declining the abdominal NCCT responses were first grouped into categories identified in a previous survey of attitudes towards kidney cancer screening (personal health beliefs, practicalities, opinions of the test, attitudes towards screening, and cancer apprehension) [27]. Each reason was reviewed by at least two researchers (AG, JUS or JK). Sub-codes within each category were then developed and agreed through discussion between those three researchers and the number of times each sub-code mentioned was counted. Each reason could be included under multiple sub-codes.

Region of interest methodology

The SD of ROI included the average CT number (pixel value) and the SD about this mean. The SD informs on the overall quality of the CT images, the higher the SD the higher the noise in the image. High noise should ultimately impact diagnostic ability once a threshold level is reached.

Supplementary Statistical analysis

Descriptive analyses were used to describe the population attending T2 during YKST, those who consented to or declined the additional YKST scan and participants' views on information provided and study processes from the questionnaires. The proportion of those invited who took-up the abdominal NCCT is reported with 95% confidence intervals (CIs). Statistical significance is considered $p<0.05$.

Supplementary results

Radiology details

From the 3645 participants for whom there were data, 68 (1.8%) had to be rescanned whilst on the unit after their initial scan failed a quality check (movement or incomplete scan), only one participant needed to be recalled for repeat scan because of incomplete scanning.

256 normal YKST scans were double read by the three YKST radiologists, two (0.8%) were upgraded from a normal scan to benign urological finding on second read.

There were six radiology misses: 3 AAAs (3.1cm, 3.3cm, 3.4cm) identified on a follow up CT scan, routine stone follow-up USS and at adrenal MDT; bilateral adrenal adenomas (found on follow-up CT scan); adrenal nodule and a liver cyst (picked up on the YLST scan); and a Bosniak 2F cyst initially reported as a simple cyst.

Non-serious findings

The second commonest non-serious renal finding were small renal stones (<5mm) found in 118 (2.9%) participants. 89 (75.4%) were offered a telephone stones clinic. None required treatment for their stone at 6-month review.

There were 109 non-serious non-kidney findings in 103 participants (Table 2&S13), the commonest being in the adrenal gland (n=43, 1.1% participants), followed by the pancreas, liver and biliary system.