Summary Box CTU Definition ESUR Working Group

- CT Urography is a diagnostic examination optimized for imaging the kidneys, ureters and bladder.
- The examination involves the use of multidetector CT with thin slice imaging, intravenous administration of a contrast medium, and imaging in the excretory phase.
Summary Box CTU Indications

- CTU can be used as a first-line or a problem-solving test.
- Pre-test probabilities for cancer should be considered in protocol selection.
- Radiation-dose issues should limit the use of three-phase CTU to patients with increased risk of urological cancer (renal, ureteral, bladder).
- To date, only the performance of CTU in haematuria/TCC has been evaluated sufficiently to recommend its use as a first-line test in this setting.
- CTU can be used as a first-line test in patients older than 40 years with macroscopic haematuria or for staging TCC. In all other haematuria patients it should be used for problem-solving.
- For benign indications, a more limited CTU protocol should be performed and in selected cases a single (excretory) phase CTU can be sufficient.
- Information from nephrographic and excretory phases can be merged by use of split-bolus injections of contrast medium, thereby reducing radiation dose.
Summary Box Patient Preparation and Patient Positioning:

- Oral administration of water one hour before the study serves as a negative bowel contrast medium, promotes diuresis and avoids dehydration. It may improve delineation of ureteral segments and can facilitate the diagnosis of incidental findings.
- Alternatively, a periprocedural slow-drip of $\leq 500$ ml iv saline can be used (no effect as bowel contrast medium).
- Supine patient position is standard practice. Prone imaging has not proven superior for opacification or distension of the collecting system and ureters, but may be advantageous for the unenhanced phase.
**Summary Box Ancillary Manoeuvres:**

- Abdominal compression has not shown definite benefit in upper urinary tract distension or opacification
- Intravenous administration of a bolus of 250ml normal saline does not improve upper urinary tract distension or opacification in a clinically significant way
- Low-dose furosemide is the most promising ancillary manoeuvre
  - homogeneous low-density of the excreted CM in the urinary tract
  - improved opacification of the distal ureteral segments
  - possibility of shorter scan delay for excretory phase imaging
  - allows detection of most ureteral stones within the opacified urine, which may reduce the need for unenhanced imaging for stone detection
- Caveats of furosemide use:
  - contra-indicated in patients with: allergy to sulphonamide drugs, acute renal insufficiency, acute glomerulonephritis
  - not recommended in patients with: hypotension, acute renal colic or complete urinary obstruction, patients at risk for contrast nephropathy
  - dehydration should be corrected by oral or intravenous hydration, especially in older and debilitated patients
Summary Box Contrast Medium Injection, Scan Phases and Test Images

- Adapt CM dose to the patient's weight (1.7-2.0 ml/kg of 300 mgl/ml)
- CM can be injected as single bolus or as split-bolus
  > Single bolus (300 mgl/ml):
    > single bolus: e.g. 125-150 ml CM at 2.5-3 ml/s
  > Split bolus (300 mgl/ml):
    > 1st bolus: e.g. 75-100 ml CM (1.0-1.4 ml/kg) at 2-3 ml/s
    > 2nd bolus: e.g. 50-75 ml CM (0.7-1.0 ml/kg) at 2-3 ml/s
    > 5-6 minutes interval between first and second CM bolus
  > Adapt volumes if a different CM concentration is used
- Delays with single bolus CM injection are for nephrographic phase 90-120s and for excretory phase 600-960s after the start of the CM injection
- Delays with split bolus CM injection are for nephrographic-excretory phase 600-960s following the start of the first CM injection and 90-120s following the start of the second CM injection
- Excretory phase delay may be shortened to 450-480s when using 0.1mg/kg iv furosemide
- The number of obtained phases is related to CM injection scheme - generally three phases (unenhanced, nephrographic, excretory) are obtained with single bolus injections and two phases (unenhanced, nephrographic-excretory) with split-bolus injections
- Low-dose, single-slice test images may be useful for individualized and optimized timing of excretory phase image acquisition (to maximize opacification of the mid- and distal ureters).
Summary Box CTU Acquisition Parameters

- The effects of overrange should be taken into consideration when optimizing CT protocols - its effect can be minimized by using narrow collimation and low pitch, reconstructing thin slices, and avoiding small craniocaudal ranges.

- Even though high-resolution (HR) for all scan phases is most optimal, lower resolution (LR) may be acceptable for unenhanced (and nephrographic) phases.

- Based on a maximum (average) craniocaudal range of 480mm and breath-holds (BH) of 10-20s (longer for 4-slice), table feed should be in the range of 12-24mm/rot.

- **Suggested acquisition parameters for different CT systems are (see table):**
  - 4-slice HR 4x1-1.25mm pitch 1.5-1.8 - LR 4x2-2.5mm pitch 1.2-1.5
  - 16-slice HR 16x0.75-1.25mm pitch 0.8-1.2 - LR 16x1-1.5mm pitch 0.7-1.0
  - 64-slice: 64x0.5-0.625mm pitch 0.5-0.7 (pitch 0.7-0.9 if shorter BH)

- Usually, a complete abdomen-pelvis CTU is performed with unenhanced and excretory phases, while only the abdomen is examined during the nephrographic phase.

- When the patient is at increased risk for malignancy, it may be beneficial to extend the nephrographic phase to include the entire abdomen-pelvis. The other phases can then be limited to start at the level of the upper pole of the kidney.
Summary Box CTU Reconstruction Parameters

- Spatial resolution is not identical to voxel size, as it depends on the image reconstruction kernel and the effective slice thickness.
- Reconstruction parameters will be determined in part by PACS capability.
- Thin-slice image sets with near-isotropic resolution should be reconstructed at overlapping intervals using a slice thickness that is slightly larger than the slice collimation.
- When thin slice images are used, data overload can be contained by using a reduced reconstruction overlap of 20% or even less.
- Reconstruction index should not be lower than in-plane resolution.
- Suggested reconstruction parameters for different CT systems are (see table):
  > 4-slice HR 1.25-1.5mm index 0.7-1.2mm - LR 2.5-3mm index 1.5-2mm
  > 16-slice HR 0.8-1.5mm index 0.7-1.2mm - LR 1.5-2mm index 1.2-1.5mm
  > 64-slice: 0.75-1.0mm index 0.7-0.8mm
- Image reconstruction kernel: medium smooth or standard.
- For image viewing 3-5mm thick-MPR can be generated (interactively) from overlapping thin-slice reconstructions (acquire thin - view thick approach).
Summary Box Post processing Parameters

- MPR is the standard viewing method for volumetric CT and can be created non-interactively by CT technicians on the CT console or interactively by reading physicians on a 3D workstation.
- Optimal MPR thickness for evaluation in any desired imaging plane is between 3-5mm in normal-sized patients.
- A variety of 3D views (Curved MPR, AIP, MIP, VR) can be added interactively on 3D workstations for documentation and communication with referring physicians.
- 3D images (especially thick-slab images > 5mm) should always be read together with the appropriate source images.
Summary Box Radiation Dose

- Radiation doses should be expressed in the standardised dose parameters volume CTDI, dose-length product (DLP) and effective dose.
- Currently volume CTDI is most useful for protocol comparisons between CT systems, while DLP can be used for diagnostic reference levels.
- Whenever possible, combined (XYZ) tube current modulation with or without 3D noise filtering should be used to contain radiation dose at diagnostic image quality, but optimal noise indices are currently unknown.
- Low tube voltage (90-100 kV) is a good way to increase contrast-to-noise ratio, especially in the low-dose range.
- Preliminary data on low-dose CT show that significant dose reductions are possible.
- Suggested low-dose values for specific phases in 60-80 kg patients are:
  - Unenhanced - abdomen/pelvis: CTDIvol 2-3 mGy - DLP 90-135 mGy cm (400mm*)
  - Nephrographic - abdomen: CTDIvol 7-8 mGy - DLP 175-200 mGy cm (200mm*)
  - Excretory - abdomen/pelvis: CTDIvol 5-6 mGy - DLP 225-270 mGy cm (400mm*)
- For patients at high-risk for malignant disease higher dose levels can be used:
  - Nephrographic - abdomen: CTDIvol 9-12 mGy - DLP 225-300 mGy cm (200mm*)
  - Excretory - abdomen/pelvis: CTDIvol 9-12 mGy - DLP 405-540 mGy cm (400mm*)
(* lengths indicate average planned range, in DLP overrange of 50mm included)
- Patient doses should be adapted to patient weight (categories)
Summary Box Proposed Approach to CTU

- Most published data has a relatively low level of evidence
- We propose a differentiated approach as the next logical step in the evolution of CTU with different CTU techniques used for different patient populations and clinical scenarios
- If only the excretory phase is relevant, a low-dose split-bolus one-phase (combined nephrographic-excretory phase) CTU is recommended
  
  *Indications include: anatomical variants of the urinary system, iatrogenic ureter trauma, CTU as add-on to evaluation of acute flank pain.*

- For more comprehensive patient evaluation, when CTU is used as a problem-solving test, a low-dose split-bolus two-phase CTU (unenhanced and combined nephrographic-excretory phases) is recommended
  
  *Indications include: chronic symptomatic stone disease, PCNL planning, complex infections, urinary diversions, and scenarios with lower pre-test probability of malignant disease - e.g. haematuria in younger patients, extra-urinary tumours of the abdomen affecting the urinary tract*

- If a high pre-test probability of malignant disease is present, a high-dose split-bolus two-phase CTU or a high-dose single-bolus three-phase CTU (unenhanced, nephrographic, and excretory phases) is justified
  
  *Indications include: evaluation of macroscopic haematuria in older patients, hydronephrosis from malignant causes, and staging of TCC*

- For problem cases with highly asymmetrical CM excretion due to unilateral obstruction, availability of a dedicated protocol with a much longer and individualized delay of the excretory phase or biphasic excretory imaging is beneficial