

CT urography. A review of the literature

Urografía por TAC. Una revisión de la literatura

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Summary

Objective: Detailed review of the CT urography technique, evaluation of the advantages and disadvantages of the existing protocols, improvement of the technique, and current indications of the study to provide an algorithm that facilitates the selection of the most efficient protocol based on evidence. ***Methods:*** This article reviews the most relevant publications in the literature, using the Pubmed database on the CT urography protocol, emphasizing single bolus and split bolus techniques, current recommendations, and study indications. ***Conclusions:*** Both the single bolus and split bolus techniques demonstrate effective results in detecting malignant lesions in the upper urinary tract. However, the split bolus technique is particularly advantageous due to its lower radiation dose, making it preferable for patients under 60 years of age and without risk factors. For scenarios involving various benign pathologies affecting the urinary tract, the split bolus technique emerges as the optimal choice. Additionally, the adjunct use of furosemide proves to be the most effective method for enhancing distension and opacification of the upper urinary tract.

Key words (MeSH)

Multidetector computed tomography
Urography
Hematuria
Furosemide

Palabras clave (DeCS)

Tomografía computarizada multidetector
Urografía
Hematuria
Furosemida

Resumen

Objetivo: Revisar detalladamente la técnica de la urografía por TAC, evaluar las ventajas y desventajas de los protocolos existentes, el mejoramiento de la técnica y las indicaciones actuales del estudio, con el fin de proveer un algoritmo que facilite la selección del protocolo más eficiente basado en la evidencia. ***Métodos:*** Este artículo revisa las publicaciones más relevantes en la literatura, usando la base de datos de PubMed sobre el protocolo de la urografía por TAC, haciendo énfasis en las técnicas de bolo único y bolo dividido, recomendaciones actuales e indicaciones del estudio. ***Conclusión*:** Las técnicas de bolo único y de bolo dividido poseen resultados eficientes en la detección de la patología maligna que afecta el tracto urinario superior; sin embargo, debe priorizarse la elección de la técnica de bolo dividido por su baja dosis de radiación en pacientes menores de 60 años y sin factores de riesgo. En los escenarios de las diferentes patologías benignas que afectan el tracto urinario, la técnica de bolo dividido es la mejor opción. El uso de furosemida es el mejor método coadyuvante para la optimización de la distensión y opacificación del tracto urinario superior.

Introduction

Computed tomography (CT) urography is defined as any tomographic acquisition in the excretory phase of the urinary tract (1, 2). Since the advent of multidetector tomography, CT urography has become the method of choice for both anatomical evaluation and the assessment of different pathologies affecting the renal parenchyma and upper urinary tract (1, 2). This technique has replaced older methods such as excretory urography, which for more than five decades was the initial method used to evaluate urinary tract disorders. However, when compared to ultrasound, CT, and magnetic resonance imaging (MRI), excretory urography shows low sensitivity in the detection of renal masses (2, 3). The main goals of the different CT urography protocols are to achieve maximum distension and opacification of the urinary tract and to minimize the radiation dose received by the patient (2).

Since its introduction, the radiation dose in CT urography has been a cause for concern, as high doses of up to 32 mSv have been reported, which could promote the development of neoplasms secondary to this type of study. Such high radiation doses are often associated with the multiple phases performed (simple, corticomedullary, nephrographic, and excretory) (1). When performing CT urography, the most widely used protocol is the single bolus technique (Table 1), as it is simpler due to its simplicity, followed by the split bolus technique, which can be double bolus or triple bolus (Figure 1) (2, 4).

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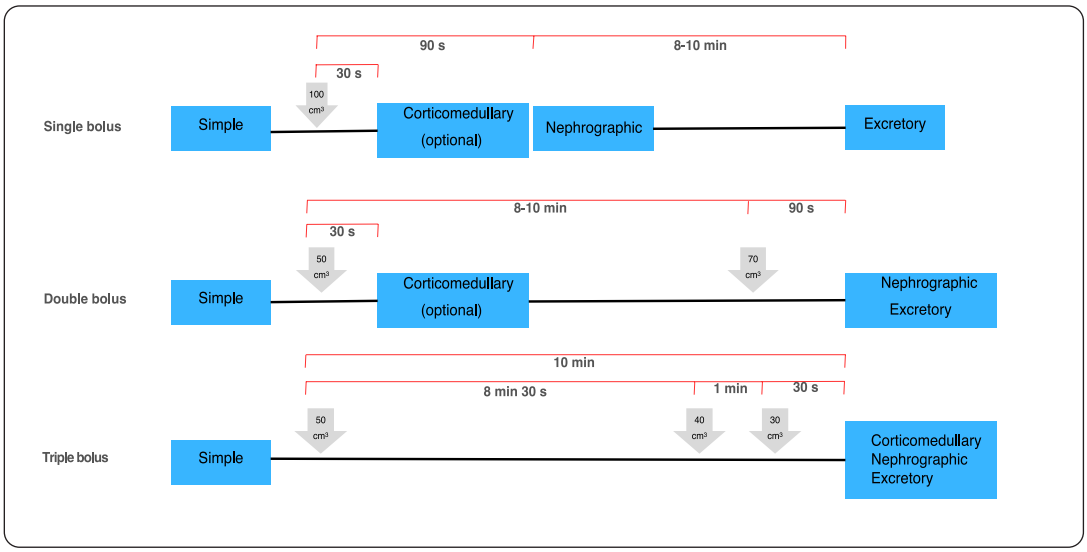


Figure 1. Example of parameters for the different existing protocols. Adapted and modified from Cheng et al. (2).

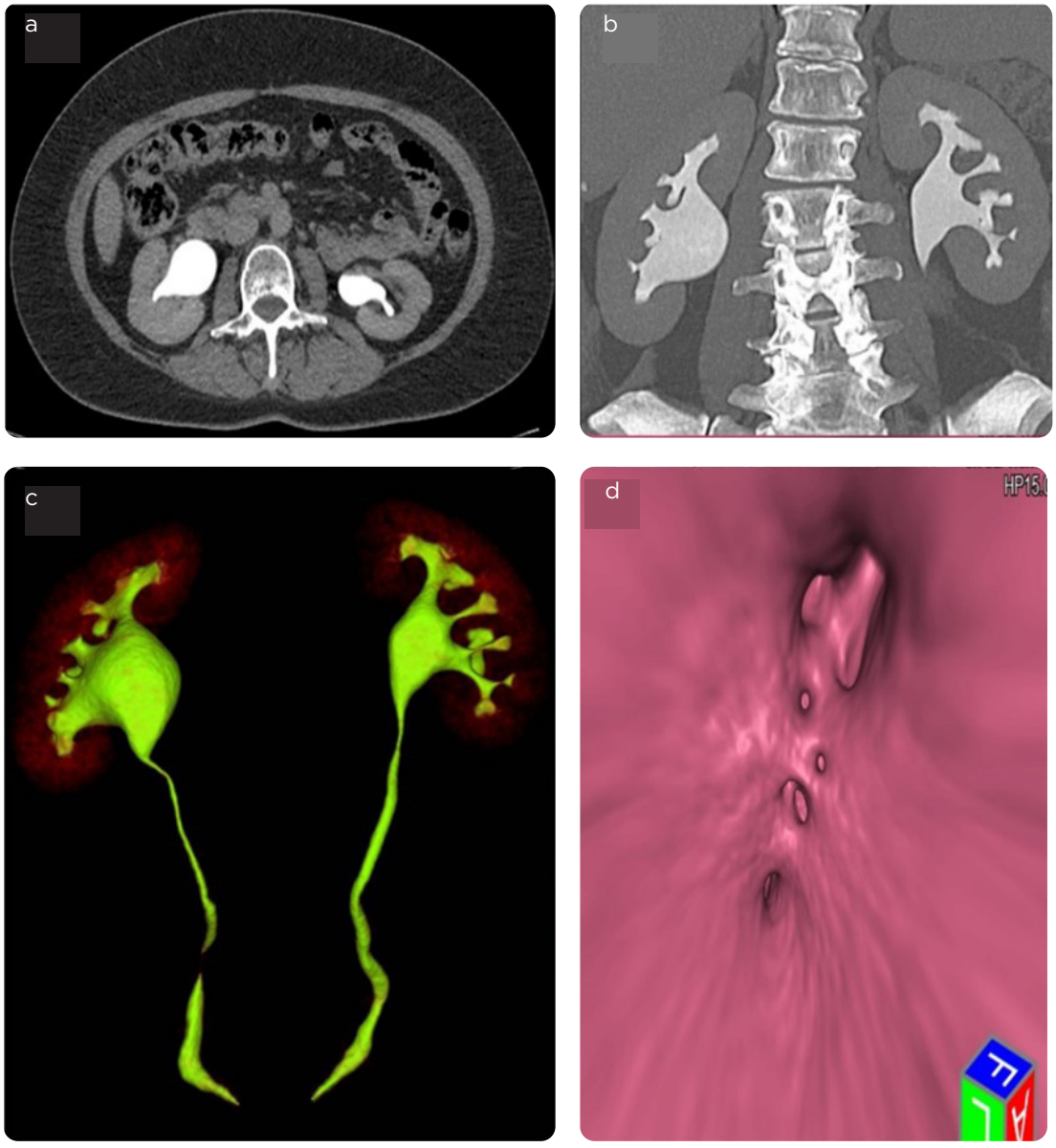


Figure 2. 68-year-old female patient undergoing investigation for asymptomatic microhematuria and hydronephrosis detected by ultrasound, studied by urography using the single bolus technique. a) Axial section: dilation of both renal pelvises. b) Coronal section, maximum intensity projection (MIP): anatomy of the renal pelvis and calyces. c) 3D reconstruction: evidence of good distension and opacification of the upper urinary tract with stenosis of the right pyeloureteral junction without dilatation of the calyces. d) Virtual endonavigation of the right renal pelvis: normal diameter of the calyces without endoluminal lesions.

Table 1. Phases of single-bolus computed tomography urography and the usefulness of each phase

Plain phase	Cortical-medullary phase (30 seconds)	Nephrographic phase (90 seconds)	Excretory phase (10 minutes)
• Detection of stones. • Provision of initial attenuation values for suspicious masses.	• Review of arterial anatomy and renal perfusion. • Observation of early enhancement of renal and bladder tumors. • Detection of transitional cell carcinoma.	• Evaluation of renal parenchyma. • Review of hypovascular lesions. • Detection of transitional cell carcinomas. • Assessment of other inflammatory or infectious processes of the kidney.	• Detection of filling defects in the urinary tract (transitional cell carcinoma, clots, lithiasis, etc.). • Discovery of urinary tract malformations. • Localization of urinary tract lesions.

Single bolus

The single bolus technique appears to be superior to the split bolus technique in detecting malignant pathology affecting the urinary tract, as it provides better distension of the excretory system, since the entire contrast bolus is used for acquisition of the excretory phase (Figure 2), which in theory would facilitate the detection of lesions of the upper urinary tract. However, its main disadvantage is the radiation dose (1, 2, 4-7). Even so, Cheng et al. demonstrated that by optimizing the technique, doses below 13.2 mSv can be achieved with low-dose protocols (2). The single-bolus technique is characterized as a dynamic study of the urinary tract, which involves a simple phase, corticomedullary phase (35 seconds), nephrographic phase (90 seconds), and excretory phase (10 minutes), each with a different purpose (Table 1). Most institutions use three-phase protocols—simple, nephrographic, and excretory—leaving the corticomedullary phase for special cases in which the arterial anatomy of the kidney needs to be studied, as it rarely contributes to the definitive diagnosis. Therefore, its benefit is minor compared to the additional radiation dose when this phase is routinely added (1, 2). Morrison et al. demonstrated that with the single bolus technique, only 28.6% of cases will require repeating the excretory phase to obtain complete opacification of the upper urinary tract (8).

Split bolus

With regard to the split bolus protocol, it has the advantage of obtaining multiple phases in a single scan. Double bolus techniques combining the nephrographic and excretory phases (Figure 3) and triple bolus techniques combining the corticomedullary, nephrographic, and excretory phases (Figure 4) have been described, producing a lower radiation dose, even below 10.8 mSv when low-dose protocols are used (2, 9). Among their disadvantages is less distension of the excretory system, due to the fact that the volume of contrast medium used is lower compared to the single bolus technique, which would lead to a new excretory phase in up to almost 50% of cases (1,5-8). However, Maheshwari et al. demonstrated that the double bolus technique achieves complete opacification of the upper urinary tract in 68.4% of cases (10).

There are many discrepancies in the literature regarding the proportion of contrast medium boluses administered for the double bolus technique. Some studies have shown good results by first administering one-third of the volume for the excretory phase followed by the remaining two-thirds for the nephrographic phase, while other authors recommend a reverse ratio, initially applying two-thirds followed by the remaining one-third (1, 11). For the triple bolus technique, Kekelidze et al. demonstrated complete opacification for the intrarenal collecting system in 91%, proximal ureters in 82%, middle ureter in 68%, and distal ureters in 54% (9). In other words, both the double bolus and triple bolus techniques have proven effective in detecting urinary tract pathology, including urothelial neoplasms (2, 9-11).

Single bolus vs Split bolus

One of the main concerns of many radiology centers is incomplete opacification and partial distension of the upper urinary tract; therefore, many studies have focused on evaluating the performance of single bolus and split bolus techniques (5-8). Dillman et al. demonstrated in 26 patients that the single-bolus technique is superior in urinary tract distension but not in opacification when compared to the split-bolus technique (5). This is because the excretory phase depends on cardiac function, renal function, ureteral peristalsis, and patient position (12). Incomplete opacification in the excretory phase could become a major problem in the detection of intraluminal lesions of the urinary tract, such as neoplasms affecting the urothelium. In many cases, this would lead to repeating the excretory phase to obtain better opacification of the urinary tract, thus increasing the radiation dose administered to the patient by approximately 4.3 mSv per additional phase (13). However, it should be remembered that urothelial carcinoma is twenty-five times more common in the bladder than in the kidney and one hundred times more common than in the ureter, so it is not necessary to acquire more than one excretory phase when the upper urinary tract cannot be completely opacified (8). In fact, some studies have shown that the nephrographic phase using the single bolus technique is superior in detecting ureteral carcinomas (Figure 5) (12, 13). Rud et al. showed in their study that 43% of urothelial carcinomas might not be visible in the excretory phase, but 100% of these lesions were evident in the nephrographic phase when the single-bolus technique was used (12). Chow et al., in their study of 500 patients referred for evaluation of urinary tract abnormalities, showed that the split bolus technique was effective in detecting 100% of malignancies affecting the upper urinary tract, including those located in the ureter (14).

Similar data were obtained by Maheshwari et al., who, in evaluating 200 patients with hematuria, showed that the split bolus technique detected up to 99% of malignant neoplasms of the upper urinary tract

(10). To overcome the difficulties of adequately visualizing the upper urinary tract, Silverman et al. demonstrated that the use of 10 mg of furosemide prior to the study results in better distension and opacification of the middle and distal segments of the ureters, which are the areas of greatest concern from a pathological point of view and the most difficult to visualize with this technique (15).

In 2019, the French Society of Genitourinary Imaging brought together 42 expert radiologists to develop technical guidelines that would consolidate the best protocol for performing CT urography. Among the topics reviewed was the single-bolus technique vs. the split-bolus technique, and they reached a consensus that each patient should be individualized in order to choose the best protocol. The split bolus technique is most recommended in young patients with suspected benign disease, and the single bolus technique for patients with suspected urinary tract malignancy. However, each case must be individualized to choose the best possible protocol (1).

Is it possible to improve distension and opacification with the help of this technique?

Several methods have been described that could help improve distension and opacification of the upper urinary tract, such as abdominal compression, performing the study in the prone position, use of diuretics, hydration, and rotating the patient 360 degrees before performing the excretory phase. However, many of these methods complicate the protocol and require more time to perform the examination (1, 2, 4).

In their study, Chow et al. describe the use of an abdominal compressor, inflating it in the pelvic region and performing the sweep up to the iliac crests, after which the compressor is removed and the pelvic region is swept to demonstrate the distal ureter (14). However, the use of abdominal compressors is contraindicated in some scenarios, such as aortic aneurysms, intestinal obstruction, stomas, recent surgery, and difficulty in obese patients (2). Similarly, some authors reveal that it does not add any benefit to the quality of the study (2). In fact, the French consensus on genitourinary imaging does not support the use of abdominal compressors to improve the quality of the study (1).

Performing the study in the prone position could help improve opacification of the upper urinary tract compared to the supine position (16). However, due to the discomfort it causes and the lack of evidence, most radiology centers prefer to perform the study in the supine position (2). One of the greatest advantages of the prone position is in patients with urinary tract dilation such as hydronephrosis, because gravity improves opacification of the hydronephrotic segment (Figure 6) (16).

The use of diuretics is the most effective method for improving visualization of the upper urinary tract: it reduces the hardening effects caused by the contrast medium in the renal calyces, and there is strong evidence in favor of its use in multiple studies that demonstrate a significant improvement in the distension and opacification of the middle and lower ureteral segments, which would thus avoid the need to repeat the excretory phase when opacification is suboptimal or not optimal, thereby avoiding an increase in the radiation dose received by the patient (15, 17-21). The use of furosemide is supported by the French consensus on genitourinary imaging, which recommends the use of 20 mg intravenously before the application of the contrast medium, provided there are no contraindications for its use, such as systolic blood pressure below 90 mm Hg, acute urinary obstruction, and a history of hypersensitivity to furosemide or sulfa drugs (1, 2, 15, 17, 18). Furosemide is a loop diuretic widely used for the treatment of heart failure and other congestive conditions. It is a drug that has been proven to be safe, with adverse effects being more common when high doses are used repeatedly. Therefore, the injection of low or intermediate doses between 5-20 mg intravenously, 3 to 10 minutes before acquisition, is safe, and studies have not reported complications with these doses (1, 2, 15, 22, 23).

Oral or intravenous hydration is a method that could help improve hyperdiuresis; however, it is an ineffective and unreliable method, which is why the French consensus on genitourinary imaging does not consider it necessary to improve the quality of the excretory phase (1). Even so, other authors recommend the application of 250 mL of saline solution or the intake of 800 mL of water before the study, despite the minimal improvement in their results (2, 9, 10, 11).

Some authors recommend rotating the patient 360 degrees several times in order to mix and homogenize the contrast medium within the urinary tract, thus avoiding the layering effect, which commonly affects the opacification of the urinary tract (2, 12).

Indications

The main indication for CT urography is in the study of asymptomatic micro- or macroscopic hematuria (2). According to the American Urological Association (AUA), microscopic hematuria is defined as the presence of three or more red blood cells per high-power field in urinalysis (24-26). This definition of hematuria, together with the AUA's lack of risk stratification by age, led to an increase in the use of CT urography in adults beginning in 2012 (25). The most recent AUA update in 2020 defines specific guidelines for performing CT urography in adult patients, which classify patients as low, intermediate, and high risk (24). High-risk patients are women and men over 60 years of age, smokers of 30 or more packs of cigarettes per year, 25 or more erythrocytes in urinalysis, a history of gross hematuria, or low-risk patients in whom follow-up urinalysis showed 25 or more erythrocytes per high-power field. Only in this group of patients does the AUA recommend the use of CT urography in conjunction with cystoscopy (24). Low-risk and intermediate-risk patients should be evaluated by renal ultrasound and cystoscopy, since in low-risk patients the possibility of malignancy is 0.2 to 0.6%, and in intermediate-risk patients the most commonly found cancer is bladder cancer (24). Lisanti et al. reported zero cases of upper urinary tract malignancy in their series of 442 patients under 50 years of age with asymptomatic microhematuria who underwent CT urography (25). This result confirms that age is a decisive factor in the development of this condition, so in patients under 50 years of age, the technique with the lowest possible radiation dose should be chosen.

Other indications for CT urography include urolithiasis (which in many cases requires only a plain scan), inflammatory kidney diseases, congenital abnormalities of the urinary tract, renal papilla abnormalities, renal trauma, complications from urological or gynecological surgery, among many others (Figures 7-8) (1, 2, 27-31).

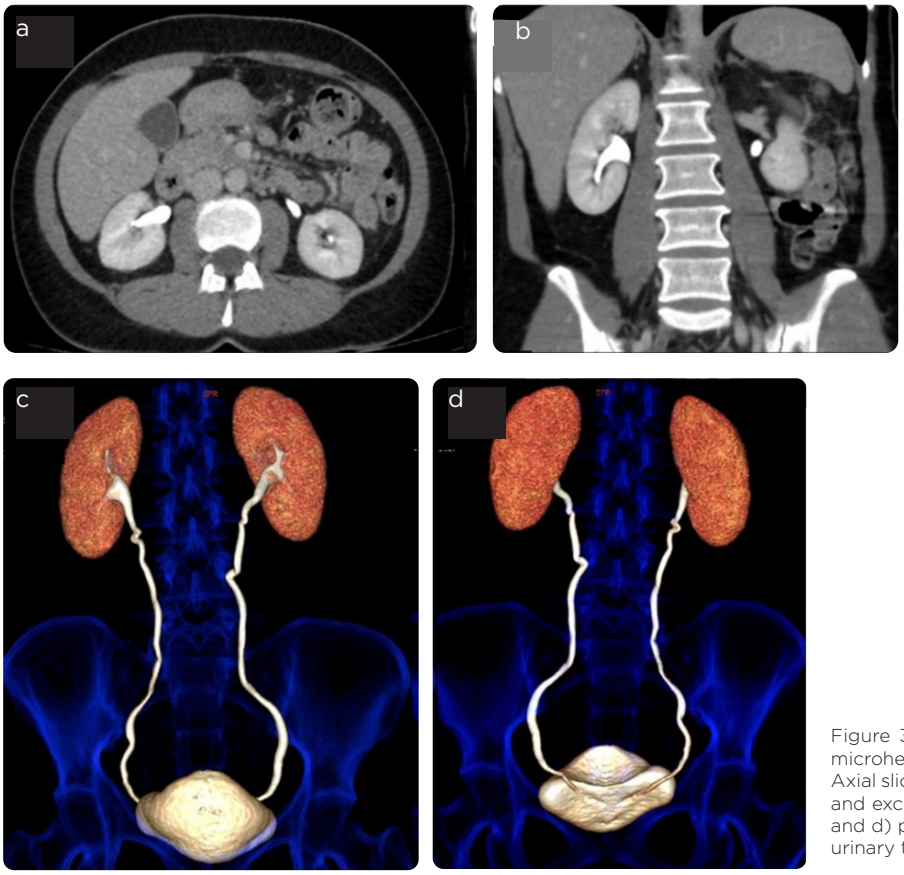


Figure 3. 42-year-old female patient with asymptomatic microhematuria, studied using double-bolus urography. a) Axial slice and b) coronal slice: simultaneous nephrographic and excretory phases. c) 3D reconstruction in frontal view and d) posterior view: complete opacification of the upper urinary tract and bladder.

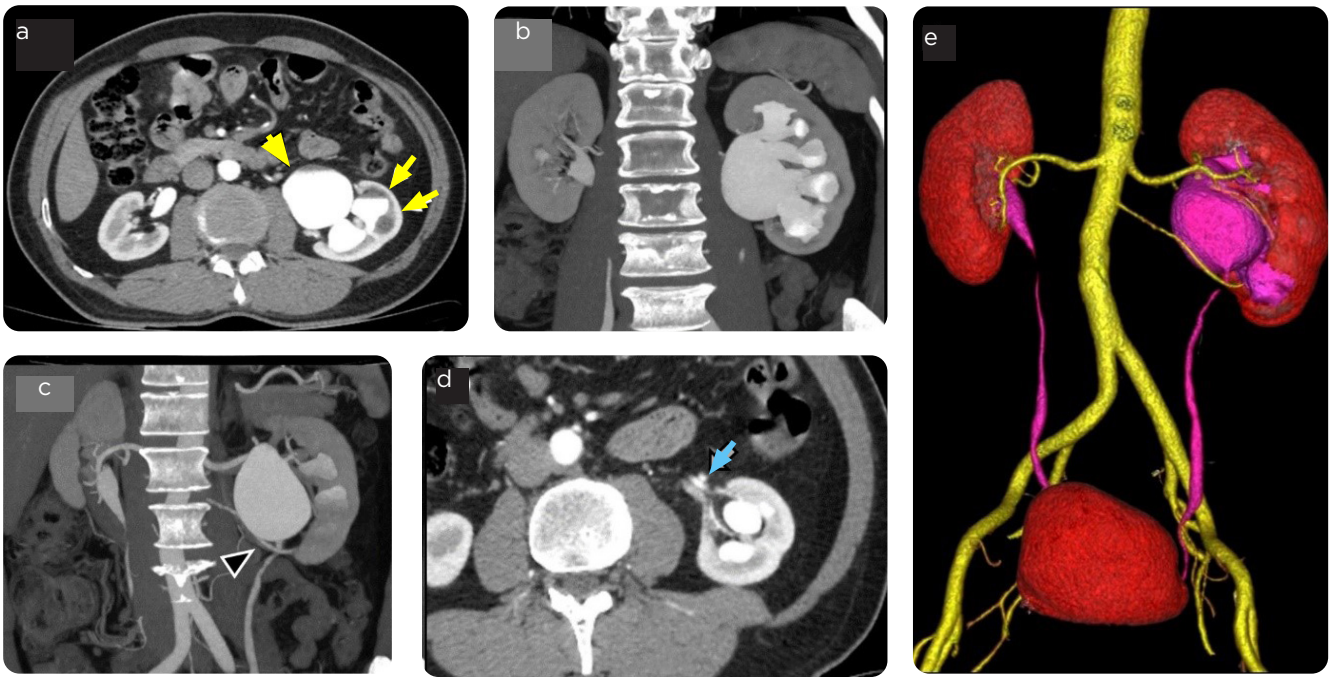


Figure 4. Asymptomatic 53-year-old man undergoing examination due to incidental finding of left hydronephrosis on routine abdominal ultrasound. Triple-bolus urography was performed, revealing findings consistent with primary pyeloureteral obstruction. a) Axial slice and b) coronal slice (MIP): left hydronephrosis with extrarenal pelvic dilatation (yellow arrowhead) accompanied by thinning of the renal cortex (yellow arrows). c) Coronal MIP image: stenosis of the left pyeloureteral junction, accompanied by a small-caliber left inferior polar renal artery (black arrowhead), a finding that could be interpreted as compression of vascular origin; however, d) the axial section shows that the ureter is anterior to the accessory artery (blue arrow). e) 3D reconstruction: confirmation that the point of obstruction is above the accessory artery, with the polar artery in this case being referred to as an innocent bystander.

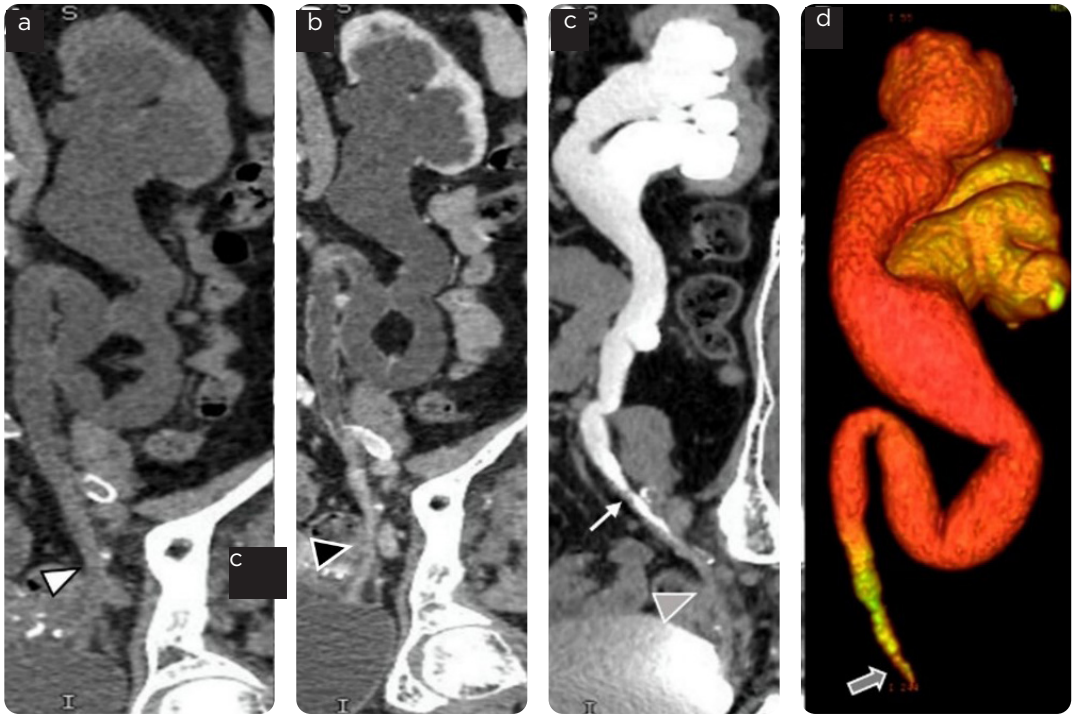


Figure 5. An 83-year-old woman with a history of heavy smoking and microscopic hematuria, studied using single-bolus urography. a) Simple phase: left hydroureteronephrosis with increased density of the ureter in its distal third (white arrowhead). b) Nephrographic phase: contrast enhancement of the distal ureter with wall enhancement (black arrowhead). c) Excretory phase: endoluminal lesion (white arrow), without opacification of the ureter in its distal third (gray arrowhead). d) 3D reconstruction: high degree of hydronephrosis with abrupt termination of the ureter (gray arrow). Note that all findings in the excretory phase were observed in the nephrographic phase.

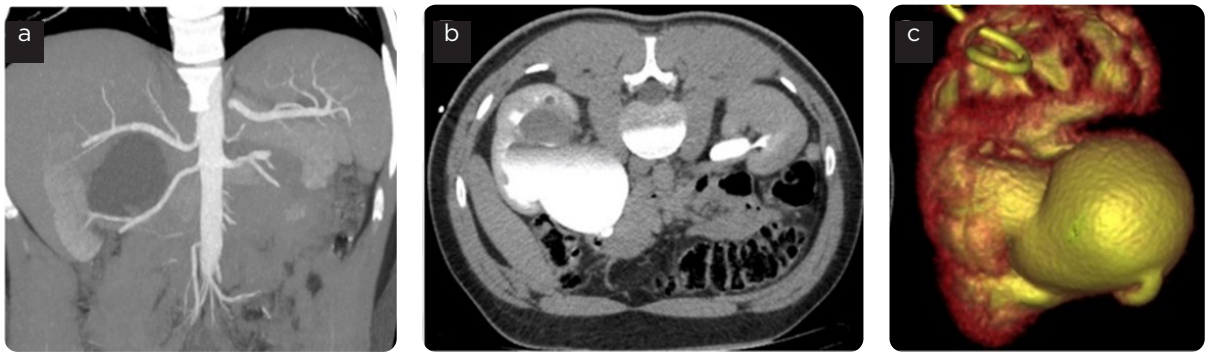


Figure 6. Single-bolus urography in a patient with vascular-related pyeloureteral junction stenosis who uses a nephrostomy catheter. a) MIP reconstruction in the coronal plane in the arterial phase: vascular compression of the pyeloureteral junction by the right inferior polar artery. b) Excretory phase in prone position: correct opacification of the hydronephrotic sac due to the effect of gravity. c) 3D reconstruction in excretory phase: kinking of the proximal ureter. Note that if the excretory phase had been performed in the supine position, it might not have been possible to demonstrate the extrinsic ureteral kinking.

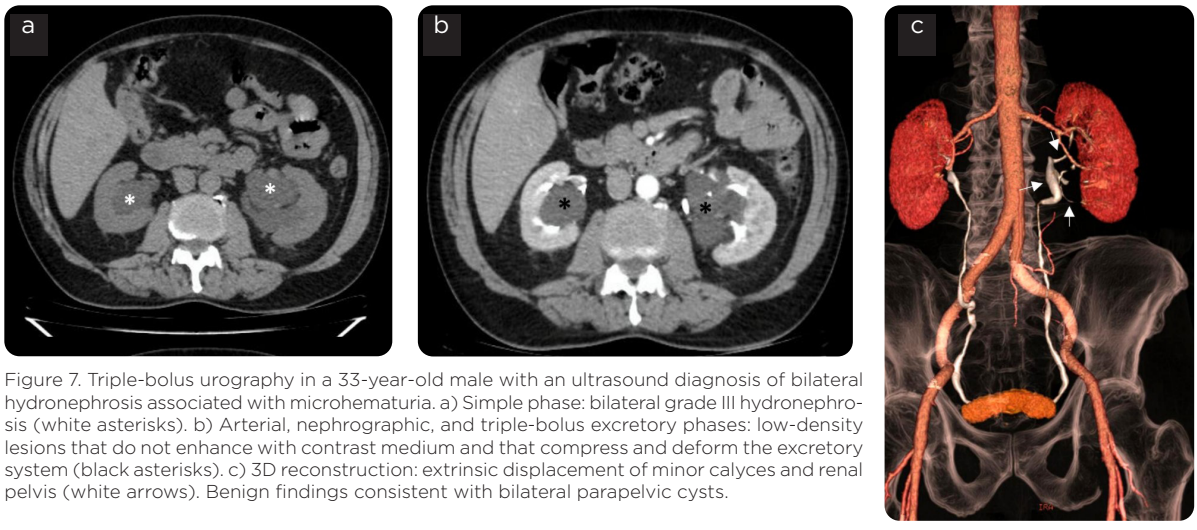


Figure 7. Triple-bolus urography in a 33-year-old male with an ultrasound diagnosis of bilateral hydronephrosis associated with microhematuria. a) Simple phase: bilateral grade III hydronephrosis (white asterisks). b) Arterial, nephrographic, and triple-bolus excretory phases: low-density lesions that do not enhance with contrast medium and that compress and deform the excretory system (black asterisks). c) 3D reconstruction: extrinsic displacement of minor calyces and renal pelvis (white arrows). Benign findings consistent with bilateral parapelvic cysts.

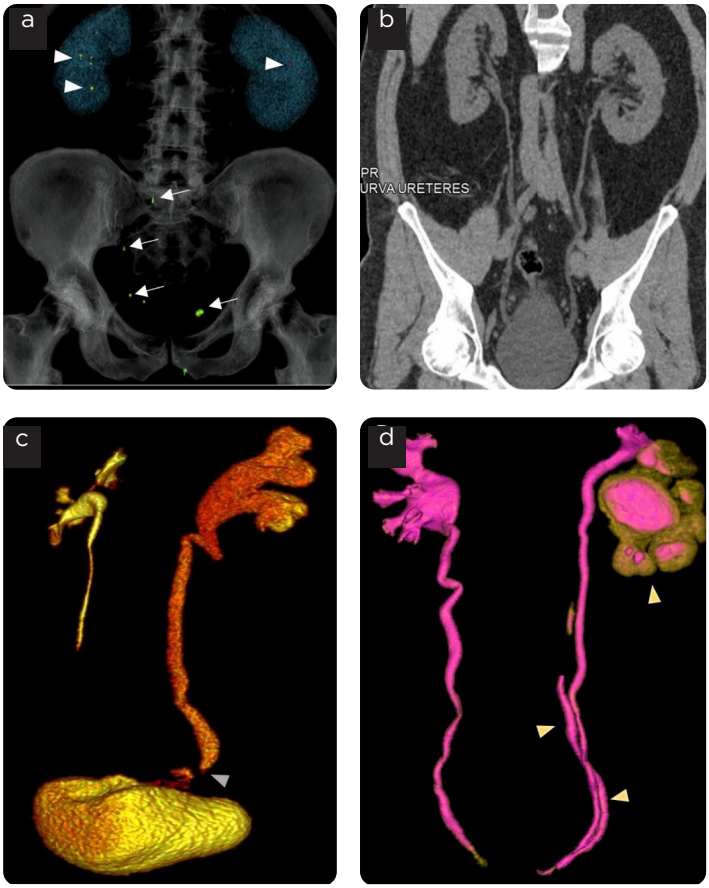


Figure 8. a) Single-phase UroTAC: multiple nephrolithiasis (white arrowheads) associated with multiple pelvic calcifications (white arrows). b) Curved MPR reconstruction of the ureters in the same patient: confirms that the calcifications are extraurinary. c) 3D reconstruction in a 50-year-old woman being studied for pain and macrohematuria following hysterectomy: iatrogenic lesion of the left distal ureteral segment (gray arrowhead). d) 3D reconstruction in the excretory phase in a 20-year-old female patient being studied for recurrent urinary tract infections with ultrasound findings of left hydronephrosis: complete double collecting system with hydronephrosis of the lower pole.

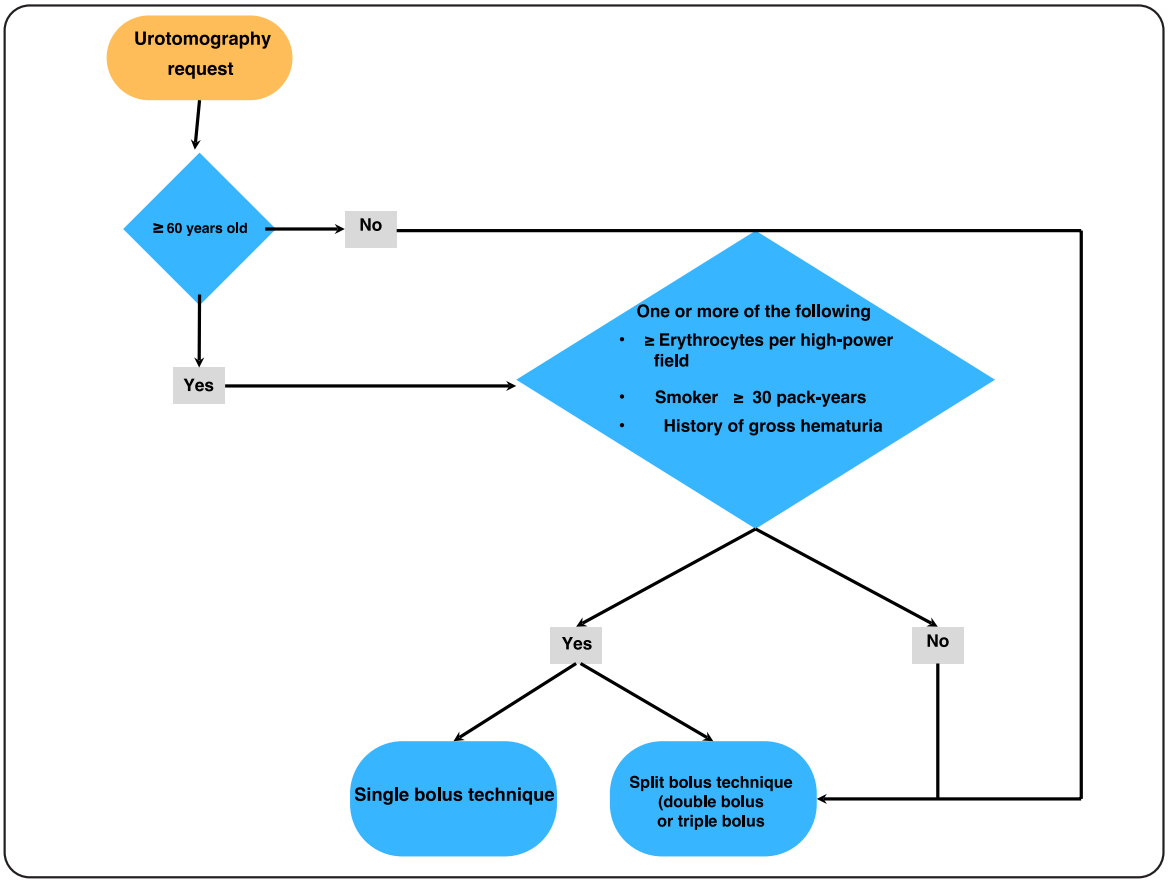


Figure 9. Algorithm for choosing between the single or split bolus technique.

Conclusion

Both the single bolus and split bolus techniques show effective results in detecting malignant pathology affecting the upper urinary tract; however, the split bolus technique should be prioritized due to its lower radiation dose in patients under 60 years of age, as the possibility of urothelial carcinoma in the ureter is rare, which is why the use of more than one excretory phase is not recommended when the ureters cannot be completely opacified. With regard to improving the technique, the use of furosemide is not mandatory for performing the study; however, the injection of 5-20 mg administered 3 to 10 minutes before the study is the only tool that has been shown to improve distension and opacification of the upper urinary tract, allowing visualization of the most critical points, which are the middle and distal segments of the ureters. In cases where malignancy of the urinary tract is suspected, the AUA only endorses the use of this diagnostic study in patients with a high risk of malignancy (over 60 years of age, hematuria >25 red blood cells per high-power field in urinalysis, smokers of >30 packs/year, and a history of gross hematuria). In this group of high-risk patients, the split bolus technique has been shown to be non-inferior to the single bolus technique for the detection of malignant pathology affecting the upper urinary tract. In patients at low or intermediate risk for malignancy, the AUA recommends only renal ultrasound, cystoscopy, or a combination of both techniques, since the incidence of malignancy is low in this group of patients and the benefit offered by CT is limited in these cases, which is why CT urography is not indicated in this population. In other scenarios involving different pathologies affecting the urinary tract, such as congenital anomalies, trauma, and suspected iatrogenesis, the split bolus technique is the best option due to its performance and lower radiation dose.

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