ORIGINAL ARTICLE

Performance of Noncontrast Multidetector Computed Tomography Compared with a Reference Standard (Surgery/ Pathology or Clinical Follow-up) in Diagnosing Acute, Nontraumatic Abdominal Pain

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Abstract

Introduction: Computed tomography (CT) with intravenous (IV) contrast is the method of choice for diagnosing and selecting treatments for surgical pathologies in patients visiting the emergency room (ER) for acute, nontraumatic abdominal pain. However, there are risks, high costs, and delays in medical attention associated with this modality. Studies have suggested performance of CT without venous contrast for diagnosing appendicitis. Nevertheless, no methodologically rigorous studies have evaluated CT without IV contrast performance when used as the main diagnostic tool for patients with acute abdominal pain.

Objective: This study aims to evaluate the diagnostic performance of noncontrast abdominal CT and compare it with a reference standard (surgery/pathology or clinical follow-up) to detect surgical diseases in patients with acute abdominal pain.

Design: This is a cross-sectional, diagnostic test study.

Place: Hospital Universitario San Vicente Foundation (Medellín, Colombia).

Materials and methods: This is a cross-sectional convenience sample diagnostic test study of consecutively selected patients who underwent noncontrast CT of the abdomen. All patients were those who presented to the ER with abdominal complaints. All patients who consented underwent a noncontrast and IV contrast CT scans. Two radiologists with different levels of expertise independently evaluated the noncontrast tomography images to specify the diagnostic findings. Final diagnoses were collected independently from the patients' clinical histories. Patients who did not undergo surgery, their clinical histories were reviewed during hospitalization. Those who were not hospitalized had their clinical course obtained by telephone 2 weeks after being discharged.

Results: Of the 157 included patients, 19.1% underwent surgery because of an acute pathology. For noncontrast abdominal contrast tomography, values of 93.3% sensitivity (95% CI 82.7–100), 96.8% specificity (95% CI 93.4–100), 87.5% PPV (95% CI 74.4–100), 98.4% NPV (95% CI 95.8–100), 29.6 LR+ (95% CI 11.24–78.1), 0.07 LR– (95% CI 0.02–0.26), and 97.4% diagnostic accuracy were obtained. The interobserver concordance had a kappa value of 0.88.

Conclusion: Noncontrast abdominal CT performs well in differentiating medical vs surgical diseases in patients with acute abdominal pain.

Keywords: Abdominal pain, Acute abdomen, Computed tomography, Diagnostic imaging, Emergency, Emergency general surgery.

Resumen

La tomografía contrastada de abdomen es el método de elección en el diagnóstico de patologías quirúrgicas en pacientes que consultan al departamento de urgencias por dolor abdominal agudo. Sin embargo hay riesgos, altos costos y retraso en la atención médica asociados con esta modalidad diagnóstica. Algunos estudios han reportado buen desempeño del la tomografía no contrastada para el diagnóstico de appendicitis aguda. Sin embargo no hay muchos estudios con rigor metodológico que evalúen el desempeño de la tomografía de abdomen no contrastada como estudio dignóstico principal en pacientes con dolor abdominal agudo.

Objetivo: Evaluar el desempeño diagnóstico de la tomografía no contrastada de abdomen comparada con el estándar de referencia (cirugía/ patología y seguimiento clínico) en la detección de patología quirúrgica en pacientes con dolor abdominal agudo, sus diagnósticos diferenciales y la concordancia interobservador.

Diseño: Estudio transversal de una prueba diagnóstica.

Lugar: Hospital Universitario San Vicente Fundación (Medellín, Colombia).

Metodologia: Estudio de prueba diagnóstica de corte transversal con selección de pacientes de forma consecutiva y por conveniencia. Tamaño muestral de 157 tomografías simples de pacientes atendidos en urgencias con dolor abdominal agudo en quienes se solicitó tomografía simple y contrastada, sin interferir en la atención de los pacientes. Dos radiólogos con diferente experiencia evaluaron de forma independiente las tomografías simples. El diagnóstico final se recolectó de forma independiente de la historia clínica. Cuando el paciente no fue operado se realizó seguimiento durante la hospitalización y los que no fueron hospitalizados se les hizo un seguimiento de la historia clínica o llamado telefónico después de dos semanas siguientes al alta.

Resultados: Se recolectaron 157 pacientes 19.1% requirieron intervención quirúrgica por patología aguda. La TC no contrastado de abdomen tuvo una sensibilidad de 93.3% (95% IC 82.7–100), especificidad 96.8% (95% IC 93.4–100), VPP 87.5% (95% IC 74.4–100), VPN 98.4% (95% IC 95.8–100), LR+ 29.6 (95% IC 11.24–78.1); LR– 0.07 (95% IC 0.02–0.26) y exactitud diagnóstica 97.4%. La concordancia interobservador tuvo un valor kappa de 0.88

Conclusión: En pacientes con dolor abdominal agudo la tomografía no contrastada de abdomen tiene excelente desempeño para el diagnóstico de patología quirúrgica, comparable a la tomografía contrastada.

Palabras clave: Dolor abdominal, Dolor abdominal agudo, Tomografia computarizada, Imágenes diagnósticas, Cirugia general de emergencias.

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Introduction

As the first-choice diagnostic tool for studying acute abdominal pain, the abdominal computed tomography (CT) with intravenous (IV) contrast has high diagnostic performance (96.8% accuracy) for primary surgical and nonsurgical pathologies (appendicitis, diverticulitis, intestinal obstruction, cholecystitis, pancreatitis, and others).[1] For appendicitis and diverticulitis, abdominopelvic CT with IV contrast has 94% sensitivity, compared with 76% sensitivity with ultrasonography.[2] Computed tomography with IV contrast is technology that is ubiquitous in almost all medical-surgical emergency rooms (ERs). The modality consists of obtaining isotropic images and post-processing them within a few seconds. Using IV contrast improves performance in diagnosing patients with acute abdominal pain[3] but has not been compared to the modern CT without contrast.

Some studies have reported that noncontrast abdominal tomography is a first-choice diagnostic alternative for distinguishing surgical pathology in the context of nontraumatic, acute abdominal pain.[4–8] For appendicitis, 97% accuracy has been observed when compared with the final diagnosis.[4] Regarding the capacity to detect calculi, air, and intestinal obstruction, noncontrast tomography shows 100% sensitivity compared with abdominal X-ray.[6] When considering all causes of abdominal pain, noncontrast tomography has shown 95% diagnostic accuracy compared with 56% with abdominal X-ray.[7]

To date, no cross-sectional study has been conducted to evaluate the performance of noncontrast abdominal CT in patients with acute abdominal pain for diagnoses other than appendicitis. Considering that retrospective studies have shown that appendicitis can be diagnosed without IV contrast, we infer that similar results can be obtained for other pathologies associated with an acute inflammatory process.

This study aims to evaluate the diagnostic performance of noncontrast abdominopelvic CT compared to a reference standard (surgery/pathology or clinical follow-up) to detect diseases that must be treated surgically in patients with acute abdominal pain.

Materials and Methods

Research Design

This is a cross-sectional, diagnostic test study, obtained from a prospectively collected cohort of patients.

Sample Size

The sample size was determined using a formula for single diagnostic test studies while considering a 20% prevalence of surgical pathology for acute abdominal pain,[9] a 98% sensitivity, a 95% specificity, and a 5% type I error.[10] An Epidat 3.1 statistical pack was used to make estimates. The calculated sample size was 156 patients.

Participants

This study included CT images from patients over 18 years in age who underwent both IV noncontrast and contrast CT for abdominal pain lasting 1 week or less. Patients with ascites resulting from a chronic disease (renal, hepatic, or cardiac) were excluded. Participants were selected consecutively from the Hospital San Vicente Foundation (Medellin, Colombia), which is a level I emergency department, considered the highest level of care. The study was approved by the institution's corresponding ethical and research committee. This study neither intervened in nor altered the provision of healthcare services, and the researchers explained to the patients that the imaging they had undergone and their clinical histories would be reviewed confidentially for the purposes of the study. An informed consent was obtained from all patients.

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Diagnostic Methods

Index Test Noncontrast Abdominal Tomography

Following the institution's protocol, patients were administered 900 mL of an oral contrast medium with a low concentration of barium or iodine 1–2 hours prior to the study.

Non-IV contrast-phase images were obtained using multidetector CT with 64-slices (GE LightSpeed VCT). The parameters used followed the manufacturer's suggested protocol and have been established at our institution: slice thickness 1.25 mm, reconstruction interval 1.25, pitch 1.3, rotation time (second), modulate dose radiation. Images were reconstructed to 2–3 mm for the three units and copied onto CDs for each patient; no clinical history information was included. The researchers administered an iodine IV contrast medium [(Iohexol) Omnipaque or (Ioversol) Optiray] through a #20 or 22 G venocath in the antecubital vein or in the back of the hand with a mechanical injector at a speed of 3 mL/second. Images were obtained in the portal phase 70 seconds after injecting the medium and covered the region from the thorax down to the pubic area.

A radiological diagnosis was recorded in a prespecified format that contained the most common acute abdomen diagnoses (appendicitis, diverticulitis, cholecystitis, pancreatitis, intestinal obstruction, urolithiasis, etc.). The surgeon evaluated the IV contrast multidetector computed tomography (MDCT) results without knowing the results of the noncontrast MDCT and proceeded accordingly.

Each patient's noncontrast MDCT results were separately evaluated 1–2 months after they were taken by two radiologists. The radiologists were blinded to the results from the contrast study and to the clinical course of the patient. These radiologists were a general radiologist and an ER radiology subspecialist, with 4 and 15 years of experience, respectively.

Benchmark Test (Surgical/Pathology Description or Clinical Follow-up)

The pathological results obtained from surgery and the description of surgery were considered benchmark tests. If there was doubt regarding whether surgery was necessary, the surgeon helped

provide a consensus (while being blinded to the tomography results).

For patients who did not undergo surgery, clinical records were reviewed. If a patient had been in the hospital for 72 hours or more, verification that the attending physician rejected a diagnosis of an acute abdominal inflammatory process was obtained. If a patient was discharged before 72 hours, the patient's clinical history was reviewed to obtain information on hospital consultations after discharge. Surgical procedures related to acute abdominal pain performed within a week after discharge were the primary parameter reviewed. If there were no records of a new visit to the hospital, then patients were called 2 weeks after being discharged to determine whether they underwent surgery within a week after discharge.

Analysis

The noncontrast tomography results were compared with the benchmark test results to estimate diagnostic performance according to sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive probability ratio (LR+), negative probability ratio (LR–), overall predictive value, and diagnostic accuracy.[11]

Cohen's kappa was used to evaluate concordance between observers. The scale proposed by Landis and Koch[12] was used to classify calculated kappa values: indices between 0 and 0.2 represented minimal concordance, between 0.21 and 0.4 regular concordance, 0.41 and 0.6 moderate concordance, between 0.61 and 0.8 substantial or strong concordance, and between 0.81 and 1 represented perfect or excellent concordance.

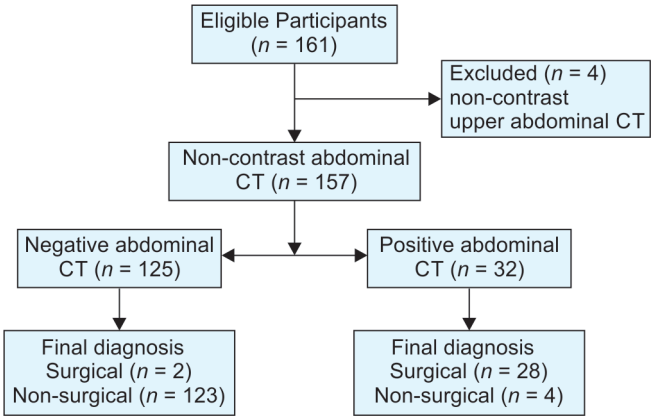
Index test data were recorded in a database using Excel, and benchmark test data were also identified and recorded. The radiologists did not know the results from the benchmark test when evaluating the contrast tomography images.

STATA 12, SPSS 20, and Epidat 3.1 were used to calculate performance and concordance values.

Results

In total, 157 patients who underwent noncontrast abdominal tomography and met the inclusion criteria were selected between January 2015 and February 2016 (Flowchart 1). The patients' characteristics are shown in Table 1.

Flowchart 1: Flow diagram showing participant identification and management



Total 34 (21.6%) of the 157 patients underwent surgery; among this group, 30 underwent surgery due to an acute inflammatory process. Of the four patients without an acute pathology, two had a tumor pathology (adnexal masses and an iliac ganglion mass resulting from the recurrence of a sarcoma, which caused acute pain), and one patient had an intestinal obstruction identified as being caused by a tumor; however, this lesion was not reported in the surgical description or the pathology specimen. Another patient was diagnosed with appendicitis via IV contrast CT, but no histologic criteria for this diagnosis were found in the pathology report.[13] Two diagnoses of hollow viscera perforations were found in surgical descriptions: one resulting from limb mesenteric thrombosis and the other from pelvic peritonitis, which caused adjacent distal ileum inflammation.

Diagnostic Performance

The values calculated for sensitivity, specificity, PPV, NPV, LR+, LR-, and diagnostic accuracy are described in Table 2 along with their corresponding confidence intervals.

Radiologist 1 identified four false-positives and two false-negatives.

The false-positives for the index test were two cases of internal hernia in patients who had underwent a gastric bypass, one case of appendicitis, and one case of ovarian torsion (which was handled as a hemorrhagic cyst). Based on the results from clinical follow-up, none of these patients required surgery.

The false-negatives corresponded to one case of appendicitis and one case of acalculous cholecystitis.

Radiologist 2 identified five false-positives and three false-negatives.

Three of the false-positives agreed with those identified by observer 1. For the other two, there was one case of cholecystitis in a patient with right-sided pyelonephritis and one case of ovarian torsion in a patient with mucinous cystadenoma whose pathology did not reveal ischemia of the compromised ovary.

Table 1: Demographic and clinical characteristics

Characteristics	*Total*
Age (years)	
Median	47
Rank (min–max)	18–92
Sex–male	42 (26.8%)
Surgical per reference standard, *n* (%)	30 (19.1%)
Nonsurgical per reference standard, *n* (%)	127 (80.9%)

Table 2: Estimate of diagnostic performance and precision

Noncontrast abdominal CT	*(%)*	*95% CI*
Sensitivity	(28/30) 93.3	82.7–100
Specificity	(125/127) 96.8	93.4–100
PPV	(28/32) 87.5	74.4–100
NPV	(123/125) 98.4	95.8–100
LR+	29.6	11.2–78.1
LR–	0.07	0.02–0.26
Diagnostic accuracy	(28/157) + (125/157) 97.4	

For the false-negatives, two patients were not diagnosed with appendicitis: one was diagnosed with ileocolitis, and the other was diagnosed with acalculous cholecystitis, in agreement with observer 1.

See Tables 3 and 4 for the detailed results.

Concordance

The kappa index for between-observer concordance in determining surgical pathology was 0.88 (95% CI 0.78–0.97); for the identified affected organs, it was 0.89 (95% CI 0.82–0.97); and for differential diagnosis, it was 0.87 (95% CI 0.81–0.93).

Discussion

Nontraumatic acute abdominal pain is a common cause for ER consultation,[14,15] representing approximately 4–5% of ER visits. An accurate diagnosis is necessary because inaccuracy or late diagnosis can increase morbidity and mortality by 8–20% in patients over 80 years old. Inaccurate diagnoses may result in unnecessary laparotomy or a missed diagnosis. In addition, hospital stays tend to be increased for patients with nonspecific abdominal pain, which often has a benign course and tends to improve 2–3 weeks after evaluation.[16,17] Powers et al. reported that the frequency of hospital admission for acute, nonspecific abdominal pain dropped from 27.4% in 1972 to 18.3% in 1993, which was attributed to advances in diagnostic technology.[14]

Abdominal CT with IV contrast is a widely used diagnostic tool, especially in ERs.[18,19] Nevertheless, routine CT with IV contrast may be inappropriate for patients with either a high or low pretest probability for a surgical pathology. The intravenous contrast medium is not necessary in most of those cases, and avoiding it can reduce both risks and costs for the patient;[4,9] noncontrast studies are a viable alternative that often provides valuable information. The inherent potential risks associated with the use of contrast medium range from slight-to-severe potential allergic reactions to nephrotoxicity, which affects anywhere from 0.6 to 12.1% of patients. Patients at the highest risk include those with a creatinine level over 1.8 mg/dL; those with a creatinine level below 60 mL/minute/1.732; those with preexisting renal disease, diabetes, dehydration, or cardiovascular disease; those taking diuretics; those over 60 years in age; those presenting with multiple myeloma, hypertension, or hyperuricemia; those receiving multiple doses of contrast medium in less than 24 hours;[20] and those receiving radiation. The use of contrast medium in these patients prolongs waiting time and increases healthcare costs.[18,19,21,22] Thus, physicians must seek alternatives to contrast tomography for the initial diagnosis of patients with acute abdominal pain.

Abdominal sonography is not routinely used for such patients because its performance is poor in many cases, which can delay decision making and increase costs.[2,23] Van Randen et al. reported a 94% sensitivity for appendicitis and diverticulitis (frequent diagnoses in the current study) for CT vs 76% for sonography, although there was no difference for cholecystitis (both had 73% sensitivity). Computed tomography has the advantage of being able to detect complications related to inflammatory pathology in the gallbladder (e.g., gangrenous cholecystitis, hemorrhagic cholecystitis, emphysematous cholecystitis, and gallbladder perforation).[24]

Appendicitis is the most common cause of acute abdominal pain that must be surgically managed. For diagnosing appendicitis, noncontrast abdominal CT can detect inflammatory involvement with simple alterations to the typical configuration used for adjacent adiposity,[25,26] with a sensitivity ranging from 98.7 to 100% and a specificity ranging from 93 to 96.9%. Studies have been conducted to identify factors to rule out nonsurgical causes of symptoms and signs of appendicitis when there is an erroneous presentation. Torbati et al. evaluated the selective use of abdominal CT with IV contrast in accordance with a clinical evaluation algorithm in patients clinically suspected of having appendicitis and with no contraindications for IV contrast. For cases with an unclear

Table 4: Differential diagnoses of abdominal pain

Diagnosis	*N (%)*
Appendicitis	22 (14)
Diverticulitis	8 (5)
Intestinal obstruction	6 (3.8)
Cholecystitis	5 (3.2)
Urolithiasis	4 (2.5)
Inflammatory pathology of the uterus and/or uterine appendages	4 (2.5)
Pancreatitis	2 (1.2)
Hollow viscera perforation	2 (1.2)
Others	82 (52.2)
• Enteritis, colitis, and fecal impaction	8 (5)
• Neoplasia	4 (2.5)
• Omental infarction	2 (1.2)
• Pyelonephritis and cystitis	3 (1.9)
• Falciform cell anemia and falciform features	2 (1.2)
• Hepatic abscess	1 (0.6)
• Physician-managed ectopic pregnancy	1 (0.6)
• Pleural tuberculosis	1 (0.6)
• Nonspecific abdominal pain	60 (26.8)
Total	157 (100)

Table 3: Diagnoses for patients who underwent surgery

			Hospital treatment		
Dx	*Observer 1*	*Observer 2*	*Surgery*	*No surgery*	*Final diagnosis*
Appendicitis	21	20	23	-	22
Intestinal obstruction	6	6	1	5	6
Cholecystitis	4	4	5	-	5
Neoplasia	4	4	3	1	4
Omental infarction	2	2	1	1	2

diagnosis, contrast CT was performed. In the study, 76% of the patients did not need IV contrast, and values of 92% sensitivity, 97% specificity, and 96% diagnostic accuracy were achieved.[4] These results validate the use of noncontrast CT.[4,27–29]

Two studies compared noncontrast CT with a series of three acute abdominal X-rays (thorax and abdominal X-rays in the standing and supine positions) for all causes of abdominal pain. The results were compared against the final diagnosis obtained through surgery or through pathology or clinical follow-up if surgery was not performed. The studies were conducted in 2005 and 2009 and respectively evaluated 91 and 163 patients admitted to the ER with acute abdominal pain. A series of X-rays was performed to rule out calculi, intestinal obstruction, and air. All causes of abdominal pain found were recorded and noncontrast CT had 96% sensitivity, 95.1% specificity, and 95.6% diagnostic accuracy, whereas the X-ray series had 65% sensitivity, 95% specificity, and 77.9% accuracy. Notably, the X-rays were performed using very low doses of radiation (half of that used in current protocols), which reduce image quality. The patients were not administered any oral or rectal contrast medium.[6,7] Hill et al. retrospectively evaluated data from 661 patients who underwent CT with different contrast combinations (IV, oral, rectal, or noncontrast); 23.6% of the group did not receive IV contrast. After surgery was performed and the postoperative condition verified, a diagnostic accuracy ranging from 92.5 to 94.6% was found for CT using IV contrast. Contrast was administered to 76.4% of the sample, and the diagnostic accuracy ranged from 92.5 to 93.5% for the rest of the sample.[5]

In the present study, we evaluated the diagnostic performance of noncontrast CT for patients with nontraumatic acute abdominal pain. The results were similar to other studies with IV contrast. For surgical pathology, the diagnostic accuracy was similar to prior studies using noncontrast or IV contrast CT.[5,7,30,31] Our values were 93.3% sensitivity, 96.8% specificity, and 97.4% diagnostic accuracy, which are comparable to those reported by Tsushima et al. in a prospective study of 125 patients who underwent noncontrast and contrast CT (92.8% diagnostic accuracy with a 32% diagnostic change). Another retrospective evaluation of the use of CT in 97 patients who underwent laparotomy in an ER conducted by Weir-MacCall et al. reported a 93% diagnostic accuracy.[30,31] With current multidetector CT and its associated capacity to evaluate isotropic images, a similar resolution can be obtained in all planes with a modulated dose of radiation (less than in previous studies).[6,32]

The most frequent differential diagnosis was nonspecific abdominal pain, which corresponded to 26.8% of the participants. This value was similar to that reported in a retrospective study by Hastings et al., whose objective was to examine trends in the diagnosis and management of acute abdominal pain in studies published from 1972 to 1993; the rate of diagnosing nonspecific abdominal pain was reduced from 41 to 21.1% during this period.[15]

The interobserver concordance calculated in our study was classified as excellent, which has not been reported in prior studies.[6] One reason for this may be the dependence on an evaluator for diagnosis when using imaging, which is highly influenced by the training level. In a 120-patient, retrospective study by Chin, a kappa value of 0.27 (95% CI 0.18–0.73) was obtained,[33] whereas kappa values ranging from 0.61 to 0.88 were found in a prospective study of 163 acute abdominal pain patients who underwent tomography after first undergoing a series of X-rays.[6]

Among the limitations of this study, we include selection bias, because despite the dissemination of the study and its benefits, some radiologists did not perform noncontrast tomography or only scanned the upper or lower abdomen. This limited the representativeness of our study population and could account for a higher pretest probability in patients not included because they only underwent noncontrast examination of the abdominal area with pain. Additionally, some patients may have been classified as chronic pain patients in their medical histories and may have undergone contrast CT due to a flare up of chronic pain not previously experienced. Verification bias was managed by clinical follow-up patients based on theoretical practical knowledge of acute pathologies requiring surgery.[34] Additionally, BMI or abdominal girth was not used as part of the selection criteria in our study. Some studies have reported that performance can be improved in the case of greater intra-abdominal fat separation from intra-abdominal organs.[35–37] This issue should be considered in future studies.

Conclusion

Noncontrast abdominal CT performs well in differentiating medical vs surgical diseases in patients with acute abdominal pain. In addition, there is good concordance between general radiologists and emergency radiology subspecialists. Therefore, noncontrast CT may be used as the main tool to rule out inflammatory pathology requiring surgical intervention.

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