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Original Research

Prognostic value of Tissue Transition Projection 3D transparent wall CT reconstructions in bowel ischemia

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HIGHLIGHTS

- CT represents the main imaging technique for diagnosing bowel ischemia.
- Bowel dilatation represents a CT sign indicating poor prognosis.
- We assess the role of TTP 3D reconstruction for evaluating loop dilatation.
- TTP 3D reconstructions are a rapid and automatic tool in this field.
- A prognostic value could be proposed for TTP 3D imaging.

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ABSTRACT

Background: Multi-detector computed tomography (MDCT) represents the gold standard in patients with acute abdomen syndrome and suspected bowel ischemia. It provides a correct diagnosis and contributes to appropriate treatment planning. This study aims to evaluate the role of 3D Tissue Transition Projection (TTP) transparent wall CT reconstruction for detecting the degree of bowel dilatation and to correlate this finding with the aetiology and prognosis in patients affected by mesenteric infarction.

Materials and methods: Forty-seven patients affected by bowel infarction due to vascular obstruction (arterial in 66% of cases, venous in 34%) were assessed by MDCT examination searching for the degree of bowel dilatation (subdivided into 4 groups: entire small bowel (SB); ≥50% of SB; < 50% of SB; large bowel only). Two blinded radiologists evaluated TTP 3D transparent wall and multi-planar reconstructions. Chi square test was used to correlate CT findings with the disease course and the mortality rate. Cohen's kappa statistics was used in order to assess inter-observer agreement.

Results: The overall mortality rate was 64%, with a 90% value for arterial forms and 10% in case of venous infarctions. The entire SB ($n = 10$) or a ≥50% SB dilatation ($n = 16$) correlated with poor prognosis in all cases ($p < 0.05$); a <50% SB dilatation ($n = 16$) correlated with good prognosis in 87.5% of cases ($p < 0.05$). A large bowel only dilatation ($n = 5$) did not show a significant prognostic value ($p = 0.13$). Almost perfect agreement between the two readers was found ($k = 0.84$).

Conclusion: MDCT offers different reconstruction software for diagnosing bowel ischemia. 3D TTP transparent wall reconstructions represent a rapid and automatic tool for identifying loop dilatation, which significantly correlates with an arterial aetiology and poor prognosis.

1. Introduction

Acute bowel ischemia represents an abdominal emergency accounting for nearly 1% of patients presenting with acute abdomen syndrome. It occurs when blood flow to the bowel loops is

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compromised because of mesenteric arterial hypo-perfusion, impaired venous drainage or bowel obstruction [1–5]. In fact, the causes of intestinal ischemia can be occlusive or non occlusive. Occlusive causes are due to the embolic or thrombotic occlusion of arterial or venous vessels and account for about 80% of all cases of intestinal ischemia [6,7]. Non occlusive causes account for about 20–30% of all cases of intestinal ischemia.

Bowel ischemia could represent a transient and reversible event if diagnosed in an early phase; however, it may lead to intestinal infarction that requires surgical or interventional management [6]. Despite the new available imaging tools, mortality rate from intestinal infarction still remains very high, with reported value ranging from 60% to 90% [8–10].

Multi-detector computed tomography (MDCT) represents the main imaging technique that must be promptly performed in all patients with acute abdomen syndrome and suspected bowel ischemia. In fact, MDCT can provide a correct diagnosis and contributes to appropriate treatment planning being able to define the nature of the disease and the extent of anatomical damage [6,7].

Several CT signs have been described in this field and recently they have also been correlated to the prognosis of the disease giving an important prognostic value to this imaging tool.

Bowel loop dilatation represents one of these signs; it has been related to an increased capillary permeability within bowel walls and usually reflects an advanced stage of disease. Besides, bowel loop dilatation is typical of the arterial forms and characterized by high mortality rates [7].

The introduction of multi-detector CT devices has highly improved the diagnostic and prognostic potential for detecting CT signs of bowel ischemia with the possibility of using different image reconstruction software starting from isotropic voxels obtained by CT scanning.

Tissue Transition Projections (TTP) represent a particular subtype of Surface Shaded Volume Rendering (SS-VRT) that can be used for this purpose [11–15]. So far, no experience has been reported in this field.

This study aims to evaluate the role of 3D TTP transparent wall CT reconstruction for detecting the degree of bowel dilatation and to correlate this finding with the aetiology and prognosis in patients affected by mesenteric infarction.

2. Material and methods

2.1. Patients

We retrospectively reviewed 47 patients with bowel infarction who were examined at our department between January 2012 and May 2013. Patients were identified through a search of our electronic archive system using terms such as ischemia, infarction and intestinal necrosis. All 47 selected cases were affected by occlusive ischemia: 31 (66%) of the arterial and 16 (34%) of the venous type. Patients included 26 men (55%) and 21 women (45%), with age ranging from 46 to 86 years (mean age 69.3). Thirty of the 47 patients (64%) had died, and 17 (36%) were alive 6 months after the diagnosis. Only 30 patients (64%) underwent surgery; of these, 18 (60%) died and 12 (40%) survived. The definite diagnosis was provided by surgery, with histology of the resected intestinal segment in 30 patients. In the remaining 17 cases, the diagnosis was based on radiological and clinical data and on the disease course. All patients were examined in an emergency setting due to sudden onset of acute abdomen.

2.2. CT protocol

The CT scanners used were a 320-slice MDCT device (Aquilion One, Toshiba Medical System, Nasu, Japan; protocol: detector collimation 320 × 0.5 mm, increment 0.5, rotation time 0.5 s, mean kVp/mAs: 120/200) and a 16-slice MDCT (TSX- 101A- Aquilion 16, Toshiba Medical System, Tochigi, Japan; protocol: detector collimation 16 × 1 mm; increment 0.8 mm; rotation time 0.5 s; mean kVp/mAs 120/250). In all cases, scans were acquired before and after the intravenous injection of contrast material (120–140 ml injected at a rate of 3–3.5 ml/s), with image acquisition in the arteriolar phase, generally with a delay of 30–40 s from the beginning of contrast-agent administration, and in the venous phase, with a delay of 60–90 s from the beginning of contrast-agent administration. The data sets were retrospectively analyzed on a workstation (HP XW 6400) equipped with image reconstruction software (Vitrea 4.1, Vital Images, Minneapolis, MN, US). 3D TTP transparent wall software and multiplanar (MPR) reconstructions were used.

2.3. Image analysis

3D TTP transparent wall reconstructions and MPR images were assessed by two blinded radiologists with more than 5 years' experience in the field of abdominal CT imaging and CT image reconstruction, searching for the following parameters:

- bowel-loop dilatation, defined as a small-bowel diameter >2.5 cm and large-bowel diameter >8 cm; basing on the degree of bowel dilatation, patients were subdivided into 4 groups:
  - entire small bowel (SB) in the case of both jejunal and ileal involvement;
  - ≥50% of SB in the case of predominant jejunal or ileal involvement associated with some ileal or jejunal dilated loops, respectively;
  - < 50% of SB in the case of exclusive involvement of some jejunal or ileal loops;
  - large bowel only;
- the morphology and patency of the coeliac trunk, superior and inferior mesenteric arteries, superior mesenteric vein and portal trunk, in order to define the arterial or venous nature of the vascular occlusion causing ischemia.

3D TTP transparent wall reconstructions were used for evaluating the degree of bowel loop dilatation while MPR images for establishing the aetiology of the disease.

Post-processing time was approximately 10 min.

2.4. Statistical analysis

The sample population was initially analyzed using descriptive statistics and considering age, gender, aetiology of ischemia (arterial or venous), disease course (dead or living patient) and calculating mortality rates. The groups of patients classified basing on bowel loop dilatation as detected by 3D TTP reconstructions were correlated with treatment outcomes (dead vs living) and with the aetiology of the disease (arterial vs. venous infarctions). Statistical significance of this information was verified by applying the chi-square test and calculating p values. The obtained data were considered to be statistically significant at a p value ≤ 0.05. Cohen's kappa statistics was used in order to assess inter-observer agreement. A k value of more than 0.81 was considered to represent almost perfect agreement and values of 0.61–0.80 and 0.41–0.60 to represent substantial and moderate agreement, respectively. All calculations were performed using NCSS2007_ statistical software.

3. Results

MPR images allowed to establish the aetiological diagnosis in all cases.

By using TTP 3D transparent wall reconstructions the following data were obtained with regard to the degree of bowel dilatation.

The entire SB dilatation was found in 10 dead patients affected by arterial ischemia in all cases (Figs. 1–2). A ≥50% SB dilatation was found in 16 dead patients affected by arterial ischemia in 15 cases and venous thrombosis in the remaining case (Fig. 3).

A < 50% SB dilatation was found in 16 patients affected by arterial ischemia in 3 cases and by venous thrombosis in 13. Two out of 16 patients (12.5%) affected by venous infarction died, while in the remaining 14 cases (87.5%) a good disease course occurred (Fig. 4).

A large bowel only dilatation was found in 5 out of 47 patients (11%), 3 with arterial ischemia and 2 with venous thrombosis. Two of the 3 cases of arterial form died, while the 2 venous cases had a good prognosis.

By comparing the degree of bowel dilatation with the disease course, in all patients with SB dilatation a statistically significant correlation was found. In particular, the entire SB or a ≥50% SB dilatation correlated with poor prognosis in all cases ($p < 0.05$); a <50% SB dilatation correlated with good prognosis in 87.5% of cases ($p < 0.05$).

A large bowel only dilatation did not show a significant prognostic value ($p = 0.13$).

Almost perfect agreement between the two readers was found ($k = 0.84$).

4. Discussion

MDCT represents the gold standard for the diagnosis of intestinal ischemia with reported sensitivity, specificity, positive and negative predictive values of 64%–93%, 92%–100%, 90%–100%, and 94%–98%, respectively. In fact, it allows the visualization of the early signs of bowel ischemia and the aetiological diagnosis of the disease, which is fundamental for treatment planning in acute patients, by using high-quality MPR, maximum intensity projections (MIP), three-dimensional rendering with increased spatial and temporal resolution [6,7].

Different CT signs have already been reported in the literature for diagnosing bowel ischemia, with a different incidence in arterial or venous vascular obstructions; they have been shown to reflect the extent of anatomical damage and also a different prognostic value [6,7].

In particular, wall hyper-density, the absence of wall enhancement and bowel-wall thickening all indicate a favourable outcome, whereas loop dilatation, parietal and porto-mesenteric pneumatosis and pneumo-peritoneum/pneumo-retro-peritoneum are all indicators of poor prognosis. These findings are due to the correlation between the progression of the intestinal ischaemic damage and CT signs [2,4,6,16–19].

The experience reported in this study also confirms what already described in the literature; in fact, MDCT allowed to diagnose the aetiology of the disease in all cases and also provided important prognostic information with an overall mortality rate of 64%, a rate of 90% for arterial forms and 10% in case of venous infarctions.

Specialized 3D CT reconstruction techniques allow the visualization of the anatomical details which may be difficult to evaluate by using axial images alone. Such details may require the use of oblique or curved reconstructions, or more complex methods, such as MIP, Minimum Intensity Projection (MinIP), Surface-Shaded Volume Rending (SS-VRT) and Virtual Endoscopy [11,12].

3D reconstructions are obtained by means of dedicated computer software that can reconstruct the volumetric data of CT. The use of 3D reconstruction techniques for examining volumetric data improves the speed of interpretation, recognition, and description of the specific clinical conditions [13–15].

In case of intestinal ischemia, MPR and 3D reconstructions allow to easily detect CT findings. In fact, such reconstructions as curved MPR, MIP, Vessel Probe (VP), SS-VRT, Tissue Transition Projections (TTP) are particularly useful for the assessment of the vascular and bowel signs of intestinal ischemia [20,21].

SS-VRT represents a technique that creates a 3D visual

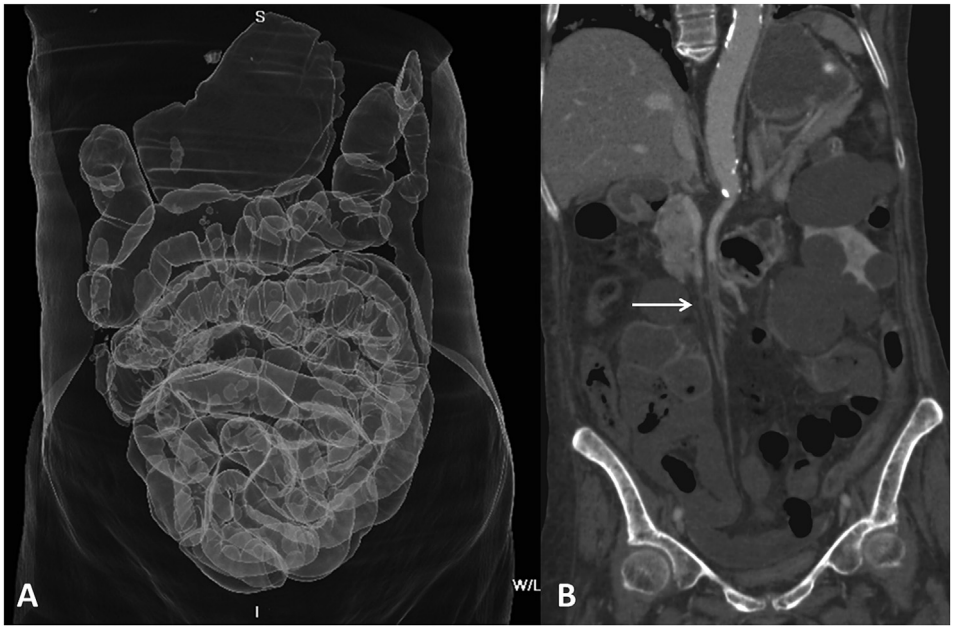

Fig. 1. A. 3D TTP transparent wall CT reconstruction shows entire small bowel dilatation in a dead patient. B. Multiplanar reconstruction on the coronal plane shows the occlusion of the superior mesenteric artery (arrow).

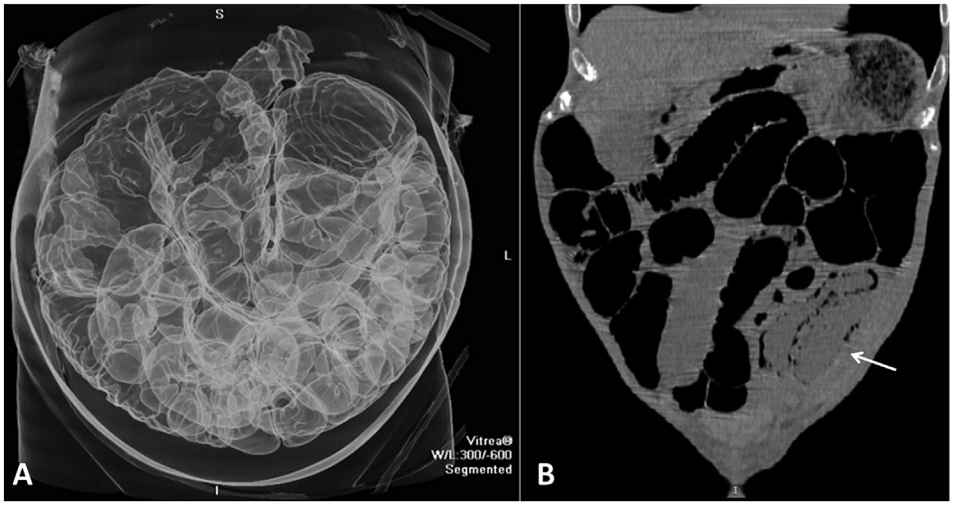

Fig. 2. A. 3D TTP transparent wall CT reconstruction shows entire small bowel dilatation in a dead patient affected by arterial mesenteric infarction. B. Multiplanar reconstruction on the coronal plane shows parietal pneumatosis of the involved loops (arrow).

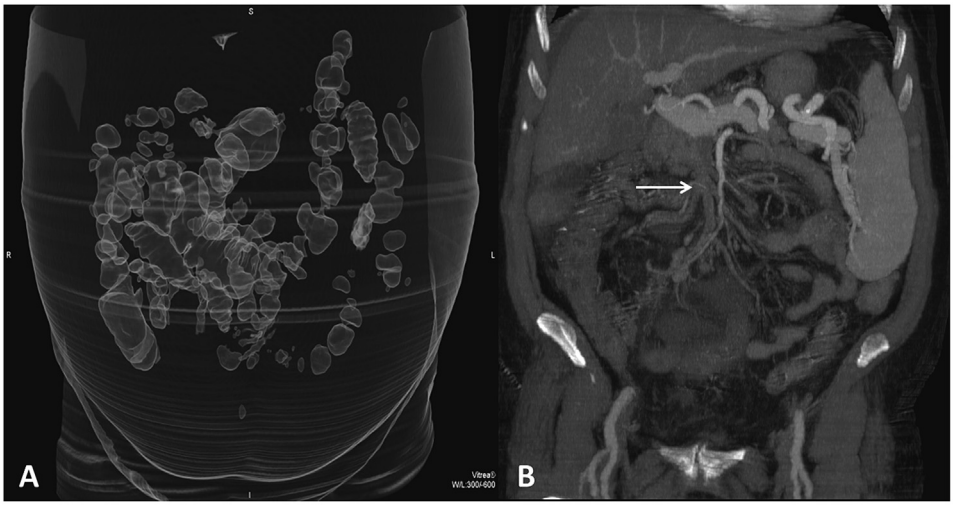

Fig. 3. A. 3D TTP transparent wall CT reconstruction shows ≥50% small bowel dilatation in a dead patient. B. Multiplanar reconstruction on the coronal plane shows the occlusion of the superior mesenteric vein (arrow).

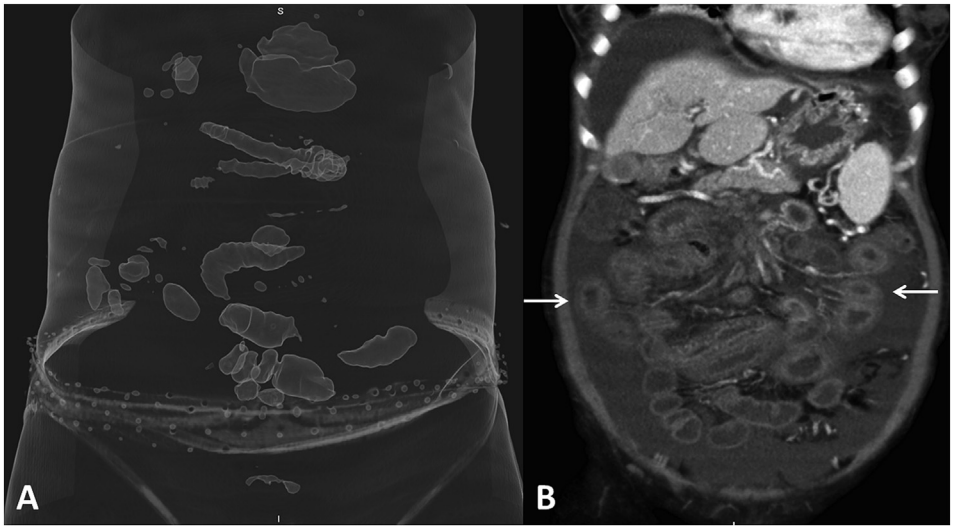

Fig. 4. A. 3D TTP transparent wall CT reconstruction shows <50% small bowel dilatation in a patient with good disease course. B. Multiplanar reconstruction on the coronal plane shows small bowel wall thickening (arrows) due to venous mesenteric ischemia.

illustration of CT volumetric data from any desired perspective and provides 3D images which are significantly superior to other volume rendering techniques [13–15]. These techniques typically select voxels to be included in a surface rendering based on a selected range of Hounsfield values. The main diagnostic utility of SS-VRT techniques is represented by its ability to reproduce with great detail structures of a specific density. Moreover, the application of a range of densitometric values corresponding to the transition zone between the bowel content (air or contrast medium) and the surrounding tissue allows to make transparent the bowel wall. These reconstructions, named TTP, could allow the evaluation of loop dilatation and its extent which represent prognostic indicators in patients affected by intestinal ischemia [13–15].

In fact, the aim of this study was to apply for the first time this kind of post-processing for evaluating loop dilatation in patients affected by bowel ischemia. In the reported experience, this kind of 3D imaging allowed to detect bowel dilatation in a reproducible, fast and automatic way. Besides, our series also confirms the negative prognostic value of this CT sign. In fact, the entire SB or a $\geq$50% SB dilatation correlated with poor prognosis in all cases and 86% of dead patients had >50% SB dilatation. A < 50% SB dilatation correlated with good prognosis in 87.5% of cases and 82% of living patients had <50% SB dilatation; only 7% of dead patients had <50% SB dilatation.

In the case of large bowel only dilatation, however, no significant prognostic value has been found in our series, with a 60% of living patients and 40% of dead patients. Further studies are needed in this field in order to verify this preliminary data.

The main limitations of our study are represented by the relatively small number of the enrolled patients and by the fact that the 3D post-processed view used in our study could reflect only the air filled portions of the bowel and not the fluid filled portions; however, in our experience, meteoric bowel dilatation or air fluid levels occurred in all cases, therefore this kind of 3D imaging seems to be reliable for assessing bowel wall dilatation and to have a prognostic value.

5. Conclusions

MDCT offers different reconstruction software for diagnosing bowel ischemia with high diagnostic and prognostic potential. 3D TTP transparent wall reconstructions represent a rapid and automatic tool for identifying loop dilatation, which significantly correlates with an arterial aetiology and poor prognosis.

Ethical approval

Retrospective study.

Funding

None.

Author contribution

Marco Moschetta, Arnaldo Scardapane, Michele Telegrafo, Nicola Maria Lucarelli, Valentina Lorusso, Giuseppe Angelelli, Amato Antonio Stabile Ianora participated to study design, data collections, data analysis and writing of the manuscript.

Conflicts of interest

None.

Guarantor

Marco Moschetta.

Unique identifying number

researchregistry1215.

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