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World Journal of Surgery and Surgical Case Reports

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Vol: 2 & Iss: 3

A Novel Triphasic CT Acquisition Protocol for Virtual Colonoscopy: A Study Hypothesis to Improve the Characterization of Colonic Stenosis and Reduce False-Positive Findings

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Citation: Urciuoli L, d' Avanzo E, Lombardi G. A Novel Triphasic CT Acquisition Protocol for Virtual Colonoscopy: A Study Hypothesis to Improve the Characterization of Colonic Stenosis and Reduce False-Positive Findings. *World J Surg Surgical Case Rep*, 2026;2(3):161-166.

Received: 26 August, 2026; **Accepted:** 02 September, 2026; **Published:** 04 September, 2026

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A B S T R A C T

Computed Tomography Colonography (CTC), also known as virtual colonoscopy, is an established minimally invasive imaging technique for the evaluation of the colon. Current CTC protocols generally include non-contrast acquisitions obtained in different patient positions, with intravenous contrast-enhanced imaging performed when clinically indicated. Although CTC provides high diagnostic accuracy for clinically significant colorectal lesions, the interpretation of focal luminal narrowing may remain challenging because transient physiological colonic contraction can mimic a true structural stenosis. Furthermore, a single contrast-enhanced acquisition may not fully characterize lesions with different or early enhancement patterns.

We propose a novel CTC acquisition protocol incorporating standardized bowel preparation and fecal tagging, controlled colonic distension, dual-position unenhanced imaging, and a triphasic contrast-enhanced acquisition consisting of arterial, portal venous, and delayed phases. The central study hypothesis is that repeated assessment of the same colonic segment over three contrast-enhanced phases may improve the specificity of CTC for the diagnosis of fixed clinically significant colonic stenosis by distinguishing persistent structural narrowing from transient physiological contraction. A secondary hypothesis is that multiphasic imaging may improve the conspicuity and temporal characterization of contrast-enhancing colonic lesions.

The proposed protocol therefore introduces a temporal-morphological dimension to CTC interpretation. This communication describes the rationale, acquisition protocol, study hypothesis, proposed endpoints, potential advantages, limitations, and framework for prospective clinical validation. The proposed approach should be considered a testable diagnostic hypothesis rather than an established replacement for current CTC protocols.

Keywords: Computed tomography colonography, Virtual colonoscopy, Colorectal cancer, Colonic stenosis, Colonic spasm, Fecal tagging, Contrast enhancement, Triphasic CT, CT colonography, Diagnostic imaging

1. Introduction

Computed Tomography Colonography (CTC) is a minimally invasive technique that enables evaluation of the entire colon using volumetric computed tomography data with two-dimensional and three-dimensional image reconstruction. CTC has become an established diagnostic option in patients with incomplete or contraindicated optical colonoscopy and in selected screening and diagnostic settings[1-4].

Technical advances in multidetector CT, image reconstruction, three-dimensional visualization, fecal tagging, and computer-aided detection have substantially improved the diagnostic performance of CTC. Adequate bowel cleansing, fecal tagging, and colonic distension are recognized as fundamental components of a high-quality examination. Imaging in different patient positions is also routinely used to improve the visualization of the colonic lumen and to distinguish mobile residual material from fixed lesions[1,2,5].

Despite these advances, the interpretation of focal or segmental luminal narrowing remains a potential diagnostic challenge. A narrowed colonic segment may represent a clinically significant structural lesion, including colorectal carcinoma, inflammatory disease, or fibrotic stenosis. However, transient physiological contraction of the colonic wall may produce a similar appearance and can occasionally mimic a true stenosis[3,6].

This problem is particularly relevant because a false-positive diagnosis of stenosis may lead to additional investigations, repeat endoscopic procedures, increased patient anxiety, and unnecessary healthcare utilization.

Another potential limitation of conventional contrast-enhanced CTC is that imaging is frequently performed during a single post-contrast phase. Although portal venous imaging provides valuable information, lesions may demonstrate different temporal patterns of contrast enhancement. Early enhancement may be more conspicuous during the arterial phase, whereas delayed imaging may provide additional information regarding persistence or washout of enhancement[1,2,5].

Based on these considerations, we propose a modified CTC protocol that combines optimized bowel preparation and fecal tagging, controlled colonic insufflation, dual-position unenhanced imaging, and three sequential contrast-enhanced acquisitions.

The central concept is that time itself may provide additional diagnostic information. By observing the same colonic segment during three contrast-enhanced acquisitions, it may be possible to distinguish a persistent anatomical narrowing from a transient physiological contraction.

2. Rationale for the Proposed Protocol

The proposed protocol is based on three complementary principles:

- Optimization of bowel cleansing and fecal tagging
- Standardized and controlled colonic distension
- Temporal assessment of colonic morphology and contrast enhancement

Adequate bowel preparation and fecal tagging facilitate the differentiation of residual stool or fluid from true soft-tissue lesions. Adequate luminal distension is equally important because an inadequately distended segment may obscure mucosal abnormalities or itself simulate a stenotic lesion[1,2,5].

The proposed protocol subsequently introduces three contrast-enhanced acquisitions: arterial, portal venous and delayed.

The rationale for this approach is not simply to acquire additional images, but to obtain temporal information regarding both lesion enhancement and luminal morphology.

A fixed structural stenosis should theoretically remain identifiable at the same anatomical location across sequential acquisitions. In contrast, transient physiological contraction may change in length, thickness, morphology, or degree of luminal narrowing, or may disappear completely during the examination.

The three contrast-enhanced acquisitions may therefore function as a form of limited temporal assessment of the colon.

3. Study Hypothesis

3.1. Primary hypothesis

The central hypothesis of this study is that triphasic contrast-enhanced CT colonography, consisting of arterial, portal venous, and delayed-phase acquisitions, can improve the specificity of CTC for the diagnosis of fixed clinically significant colonic stenosis compared with conventional CTC protocols based on a single contrast-enhanced acquisition.

The underlying rationale is that a true structural stenosis is expected to demonstrate persistent luminal narrowing across sequential acquisitions, whereas transient physiological colonic contraction is expected to show temporal variability in morphology, degree of narrowing, or complete resolution.

Accordingly, repeated visualization of the same colonic segment may provide a temporal-morphological signature that helps distinguish:

- Fixed structural stenosis, characterized by persistent luminal narrowing across the three contrast-enhanced phases; from
- Transient physiological contraction, characterized by substantial changes in luminal caliber or morphology between phases or complete disappearance of the suspected narrowing.

3.2. Secondary hypothesis

A secondary hypothesis is that the arterial phase may increase the conspicuity of lesions demonstrating early contrast enhancement, while portal venous and delayed acquisitions may provide complementary information regarding the persistence and temporal evolution of lesion enhancement.

The additional phases may therefore improve overall lesion characterization and radiologist confidence.

3.3. Null and alternative hypotheses

The primary statistical hypotheses are:

- **Null hypothesis (H_o):** Triphasic CTC does not improve the specificity of CTC for the diagnosis of fixed clinically significant colonic stenosis compared with conventional CTC.

- **Alternative hypothesis (H_1):** Triphasic CTC improves the specificity of CTC for the diagnosis of fixed clinically significant colonic stenosis compared with conventional CTC.

The primary purpose of the proposed study is therefore to determine whether the additional temporal information provided by triphasic acquisition produces a clinically meaningful reduction in false-positive diagnoses of colonic stenosis.

4. Proposed Patient Preparation

4.1. Bowel preparation

On the day before the examination, bowel cleansing is performed according to the proposed regimen:

Two sachets of Selg-Esse laxative oral powder dissolved in approximately 2 L of water.

The purpose of bowel preparation is to minimize residual fecal material and facilitate adequate evaluation of the colonic lumen.

The preparation regimen should be individualized when appropriate according to patient age, comorbidities, renal function, medications, hydration status, and institutional practice.

4.2. Fecal tagging

On the day of the examination, the patient remains fasting according to the institutional protocol.

Approximately four hours before CT acquisition, the proposed fecal-tagging regimen consists of:

40 mL of Omnipaque 350 (iohexol 350 mg iodine/mL) diluted in 1 L of water, administered orally.

The objective is to increase the attenuation of residual fluid and fecal material and thereby facilitate differentiation between tagged intraluminal material and soft-tissue lesions.

The precise dose, dilution, timing, and route of administration should be prospectively evaluated and approved according to local institutional procedures, product information, contraindications, and applicable regulatory requirements.

5. Colonic Distension

Approximately four hours after administration of the oral tagging solution, the patient is positioned on The Computed Tomography (CT) table.

A small, soft, flexible rectal catheter is gently introduced into the rectum.

Controlled insufflation is then performed through the catheter using room air. The proposed volume is approximately 1000 mL to 1500 mL, although the final volume should be adapted to individual patient tolerance and the degree of colonic distension obtained.

The objective is to achieve adequate and homogeneous distension of the colon while minimizing patient discomfort and procedural risk.

Adequate distension is particularly important for the present study because the interpretation of luminal narrowing depends on distinguishing genuine structural abnormalities from apparent narrowing caused by incomplete expansion of the colon.

6. Proposed CT Acquisition Protocol

After satisfactory colonic distension, the CT examination is performed according to the following sequence.

6.1. Baseline unenhanced acquisitions

Two non-contrast acquisitions are performed:

- Prone acquisition
- Supine acquisition

The two positions provide complementary information regarding colonic distension, residual tagged material, fluid redistribution, and luminal morphology.

6.2. Arterial-phase acquisition

A contrast-enhanced supine acquisition is performed during the arterial phase following intravenous administration of iodinated contrast according to the institution's standard contrast-enhanced CT protocol.

The arterial phase is intended to improve visualization of lesions demonstrating early or prominent contrast enhancement.

6.3. Portal venous-phase acquisition

A second contrast-enhanced supine acquisition is obtained during the portal venous phase.

This phase provides conventional post-contrast information regarding colonic wall abnormalities, surrounding structures, lymph nodes, and potential extracolonic disease.

6.4. Delayed-phase acquisition

A third contrast-enhanced supine acquisition is obtained during the delayed phase.

The delayed phase provides additional temporal information regarding lesion enhancement and, importantly, allows reassessment of the morphology of previously identified areas of luminal narrowing.

The complete proposed acquisition sequence is therefore:

Prone non-contrast → Supine non-contrast → Supine arterial → Supine portal venous → Supine delayed.

7. Temporal-Morphological Assessment of Colonic Stenosis

The principal innovative aspect of the proposed protocol is the repeated evaluation of the same colonic segment during three contrast-enhanced acquisitions.

When a suspected stenosis is identified, the radiologist evaluates:

- Anatomical location
- Longitudinal extension
- Minimum luminal diameter
- Circumferential involvement
- Wall thickness
- Symmetry
- Morphology of the transition zone
- Degree of luminal narrowing
- And changes in appearance between the arterial, portal venous, and delayed phases

A narrowing that remains substantially unchanged across all three acquisitions would be classified as a persistent narrowing and would raise suspicion for a fixed structural stenosis (Figure 1).

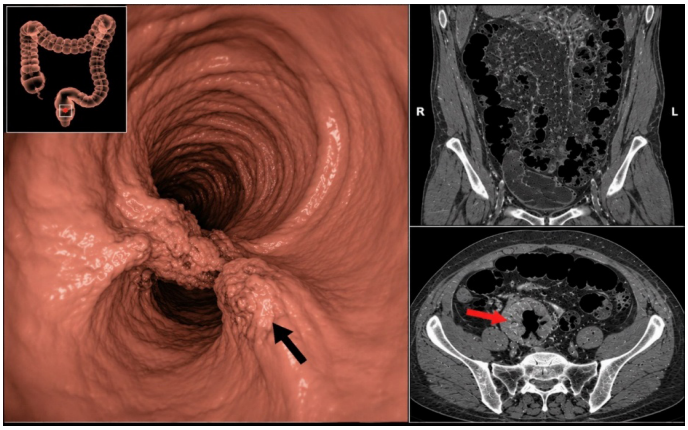

Figure 1: Virtual Colonoscopy shows a focal, irregular, asymmetric stenosis (black arrow) due to an ulcerated neoplastic mass, Axial CT image (red arrow) demonstrates circumferential wall thickening and luminal narrowing of the sigmoid colon.

Conversely, substantial variation in luminal caliber, morphology, or disappearance of the narrowing during subsequent acquisitions would favor transient physiological contraction.

This approach may provide information that is not available from a single post-contrast acquisition.

8. Operational Definition of the Imaging Hypothesis

For prospective validation, a persistent stenosis should be defined using predetermined imaging criteria.

A persistent stenosis may be operationally defined as a focal or segmental reduction in luminal caliber that remains demonstrable at the same anatomical location, with substantially similar morphology, across the arterial, portal venous, and delayed acquisitions.

A transient contraction may be defined as a narrowing demonstrating substantial temporal variation in luminal caliber or morphology or complete disappearance on one or more subsequent acquisitions.

Quantitative thresholds should ideally be established prospectively before the study begins and should not be modified according to the observed results.

The use of objective measurements of luminal caliber and wall morphology could further strengthen reproducibility and allow quantitative statistical analysis.

9. Primary Study Endpoint

The primary endpoint will be the specificity of triphasic CTC for the diagnosis of fixed clinically significant colonic stenosis.

The reference standard should preferably consist of optical colonoscopy with histopathological confirmation when a lesion is identified[1-3,6].

When histopathological confirmation is not available, appropriate endoscopic, radiological, or clinical follow-up may be used according to a predefined study protocol.

The primary analysis will compare the specificity of the proposed triphasic protocol with that of conventional CTC interpretation based on the standard acquisition strategy.

The principal expected effect is a reduction in false-positive diagnoses caused by transient physiological colonic contraction.

10. Secondary Endpoints

Secondary endpoints will include:

- Sensitivity for clinically significant colonic stenosis
- Positive predictive value
- Negative predictive value
- Number of false-positive stenosis diagnoses
- Interobserver agreement
- Radiologist diagnostic confidence
- Lesion conspicuity across the three contrast phases
- Temporal enhancement pattern of suspected lesions
- Ability to distinguish transient contraction from fixed structural stenosis
- Adequacy of colonic distension
- Adequacy of fecal tagging
- Patient tolerance
- Examination-related adverse events
- Radiation dose
- Additional clinically relevant extracolonic findings

11. Potential Diagnostic Advantages

11.1. Reduction of false-positive stenosis diagnoses

The principal potential advantage is improved specificity.

In conventional CTC, a short segment of luminal narrowing may be difficult to classify when only a limited number of acquisitions are available.

The triphasic protocol introduces repeated temporal assessment.

If the narrowing persists with substantially similar morphology throughout all three contrast-enhanced acquisitions, the probability of a fixed structural abnormality may increase.

If the narrowing changes substantially or disappears, transient contraction becomes a more plausible explanation.

This could reduce the number of patients incorrectly referred for further invasive investigation because of an apparent stenosis that represents normal physiological contraction.

11.2. Improved lesion conspicuity

The arterial acquisition may demonstrate early enhancement that could be less conspicuous during the portal venous phase.

The portal venous phase provides complementary information regarding lesion enhancement and extracolonic structures.

The delayed acquisition may further characterize the persistence or evolution of enhancement.

Thus, the protocol may provide additional information regarding the temporal enhancement behavior of a lesion.

11.3. Increased reader confidence

An additional potential benefit is increased confidence in cases in which the distinction between stenosis and transient contraction is uncertain.

Rather than relying exclusively on morphological appearance at a single time point, the radiologist can evaluate whether the finding remains stable over time.

12. Proposed Prospective Study Design

The proposed imaging protocol should be evaluated in a prospective clinical study.

A consecutive cohort of patients referred for CTC could undergo the proposed acquisition protocol.

Two interpretation strategies could then be compared:

- Strategy A: Interpretation using the conventional CTC dataset.
- Strategy B: Interpretation using the complete triphasic dataset.

Radiologists could be blinded to the reference standard and, where feasible, blinded to the alternative interpretation.

- For each suspected stenosis, the readers would record:
- Presence or absence of stenosis
- Anatomical location
- Degree of narrowing
- Morphology
- Persistence across phases
- Confidence score
- And recommended clinical management

The final diagnosis would be established using optical colonoscopy, histopathology, or predefined follow-up criteria.

This design would allow direct evaluation of whether the additional triphasic information improves diagnostic specificity.

13. Statistical Analysis

The primary analysis should compare the specificity of conventional CTC with that of triphasic CTC for the diagnosis of fixed clinically significant stenosis.

Because the two interpretations would be generated from the same patients, paired statistical methods should be considered.

Sensitivity, specificity, positive predictive value, negative predictive value, and corresponding confidence intervals should be calculated.

Interobserver agreement could be assessed using Cohen's or Fleiss' kappa, depending on the number of readers and study design.

Receiver operating characteristic analysis could be used if radiologists provide confidence scores.

A sample-size calculation should be performed before patient recruitment based on the expected prevalence of true stenosis, baseline specificity of conventional CTC, and the minimum clinically relevant improvement in specificity considered important.

Importantly, the primary endpoint and statistical analysis plan should be predefined before database lock.

14. Radiation Dose Considerations

The major limitation of the proposed approach is the additional radiation exposure associated with three contrast-enhanced acquisitions.

Current CTC practice emphasizes dose optimization. Therefore, the potential diagnostic benefit of the additional arterial and delayed phases must be balanced against their incremental radiation burden[1,2].

The protocol should incorporate contemporary dose-reduction techniques, including:

- Automated tube-current modulation
- Appropriate tube-voltage selection
- Iterative reconstruction
- Deep-learning reconstruction where available
- Optimized scan length
- And institution-specific low-dose strategies

The study should prospectively record dose-length product and, where appropriate, estimated effective dose.

The ultimate objective should not be to increase radiation exposure without demonstrable benefit, but to establish whether the additional temporal information produces sufficient diagnostic improvement to justify the additional acquisitions.

15. Patient Safety and Feasibility

The proposed protocol requires careful consideration of patient safety.

Colonic insufflation should be performed gradually by trained personnel, with continuous attention to patient tolerance and clinical contraindications.

The administration of oral and intravenous iodinated contrast requires appropriate assessment of patient-specific risk factors and adherence to institutional policies.

The feasibility of the protocol should also be evaluated in terms of examination duration, patient discomfort, breath-holding requirements, workflow, and scanner availability.

These parameters should be incorporated into the prospective study as secondary feasibility outcomes.

16. Limitations

Computed Tomography Colonography (CTC) is having some limitations as follows.

First, the proposed protocol has not yet been prospectively validated. The hypothesis that triphasic imaging reduces false-positive stenosis diagnoses therefore remains unproven.

Second, physiological colonic contraction is dynamic and may occur at variable intervals. A lesion that changes between phases cannot automatically be classified as physiological, and a persistent contraction could theoretically mimic a fixed lesion.

Third, repeated acquisitions increase radiation exposure.

Fourth, additional imaging increases examination complexity and may affect patient tolerance and departmental workflow.

Fifth, the proposed oral fecal-tagging regimen should be validated in accordance with local regulatory and institutional requirements.

Sixth, the diagnostic performance of the protocol may depend on scanner generation, reconstruction technology, bowel preparation, degree of colonic distension, and radiologist expertise.

Finally, the optimal temporal interval between arterial, portal venous, and delayed acquisitions remains to be established and should be standardized in future clinical studies.

17. Expected Impact

If the study hypothesis is confirmed, triphasic CTC could introduce a new conceptual approach to the interpretation of colonic stenosis.

Rather than considering each CT acquisition as an isolated anatomical snapshot, the proposed protocol would use sequential acquisitions to evaluate temporal stability of colonic morphology.

This could provide an additional diagnostic criterion:

persistent morphology over time → increased suspicion for fixed structural stenosis versus changing morphology over time → increased probability of transient physiological contraction.

The same temporal principle could potentially be extended to the characterization of contrast-enhancing colorectal lesions.

Importantly, these potential advantages should be demonstrated prospectively before the protocol is recommended for routine clinical use.

18. Conclusions

We propose a novel triphasic CT colonography protocol that combines optimized bowel preparation and fecal tagging, controlled colonic distension, dual-position unenhanced imaging, and arterial, portal venous, and delayed contrast-enhanced acquisitions.

The central study hypothesis is that temporal assessment of colonic morphology across three contrast-enhanced acquisitions can improve the specificity of CTC for fixed clinically significant stenosis by distinguishing persistent structural narrowing from transient physiological colonic contraction.

The protocol may also improve the conspicuity and temporal characterization of contrast-enhancing colorectal lesions.

The proposed approach should be regarded as a testable diagnostic hypothesis rather than an established clinical standard. A prospective comparative study using colonoscopy and histopathology as reference standards, predefined imaging criteria, blinded radiological interpretation, and formal assessment of radiation exposure is required to determine its diagnostic value.

If validated, this approach could represent a novel extension of virtual colonoscopy from a predominantly morphological examination toward a temporal-morphological imaging technique, potentially reducing false-positive stenosis diagnoses and increasing diagnostic confidence.

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