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REVIEW / *Abdominal imaging*

Cinematic rendering of focal liver masses

L.C. Chu*, S.P. Rowe, E.K. Fishman

The Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, 600 North Wolfe Street, Baltimore, MD, USA

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Abstract Cinematic rendering (CR) is a recently described three-dimensional (3D) rendering technique that generates photorealistic images based on a new lighting model. This review illustrates the potential application of CR in the evaluation of focal liver masses. CR shows promise in improving the visualization of enhancement pattern and internal architecture, local tumor extension, and global disease burden, which may be helpful in focal liver mass characterization and pretreatment planning.

Cinematic rendering (CR) is a recently described three-dimensional (3D) rendering technique that generates photorealistic images based on a new lighting model [1—4]. Similar to traditional volume rendering (VR), thin-slice-reconstructed computed tomography (CT) data is stacked into a 3D volume. Each isotropic voxel in the volume is assigned a color and transparency based on attenuation thresholds [5,6]. CR differs from traditional VR in the use of the lighting model. While VR uses a simple ray cast method to generate 3D images, CR uses Monte Carlo path tracing and a global illumination model that takes direct and indirect illumination into account. With CR, each pixel is formed by thousands of rays passing through the volumetric dataset and includes effects of light rays from scatter and from voxels adjacent to the paths of the rays [1—4]. CR generates photorealistic images that have the potential to more accurately depict complex anatomy. A few reports have described the use of this technique in abdominal imaging, including stomach, small bowel, and pancreas [7—9]. The application of this technique in the imaging of focal liver masses has not been previously described in detail. CR can potentially improve the appreciation of enhancement pattern and internal architecture, which are important features in the differentiation of focal liver masses. CR can also improve visualization of local tumor invasion, vascular supply, and global disease burden, which may assist with pretreatment planning and facilitate communication with referring clinicians and patients.

The purpose of this article is to illustrate the potential application of CR in the evaluation of focal liver masses, in a case review format.

* Corresponding author at: 600 North Wolfe Street, Hal B168, Baltimore 21287, MD, USA.
E-mail address: lindachu@jhmi.edu (L.C. Chu).

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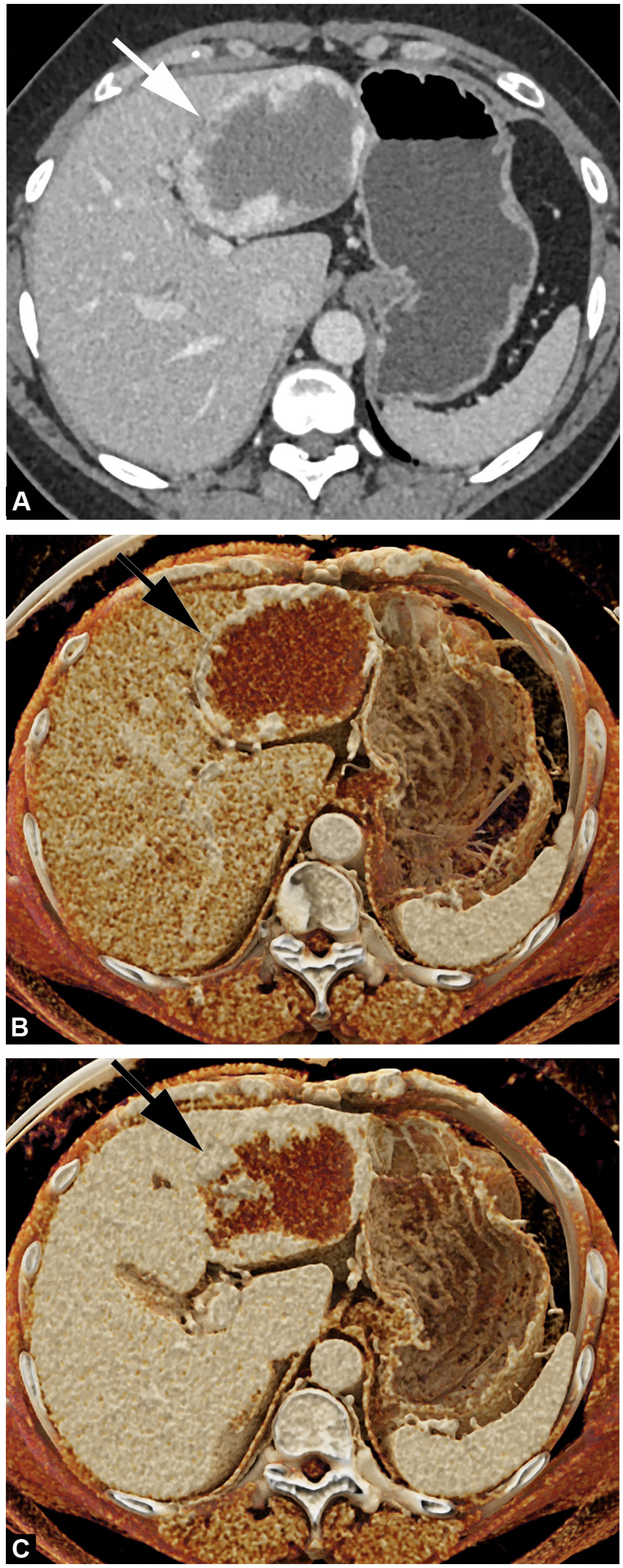

Figure 1. A 49-year-old woman with history of liver hemangioma. A. Two-dimensional CT image obtained in the axial plane during the arterial phase of enhancement shows a well-circumscribed hepatic mass in the left lateral section of the liver with peripherally nodular enhancement (arrow). B and C. CT images obtained in the axial plane with cinematic rendering during the arterial phase (B) and portal venous phase of enhancement (C) illustrate the classic enhancement pattern with peripheral nodular enhancement with progressive centripetal filling (arrow).

Figure 2. A 42-year-old woman with giant hepatic hemangioma. CT image obtained in the coronal (A & B) and axial (C) plane during the portal venous phase of enhancement with cinematic rendering shows the classic peripheral nodular enhancement of the hepatic hemangioma (arrows). The mass can be rendered translucent (B and C) to better illustrate this enhancement pattern (arrows).

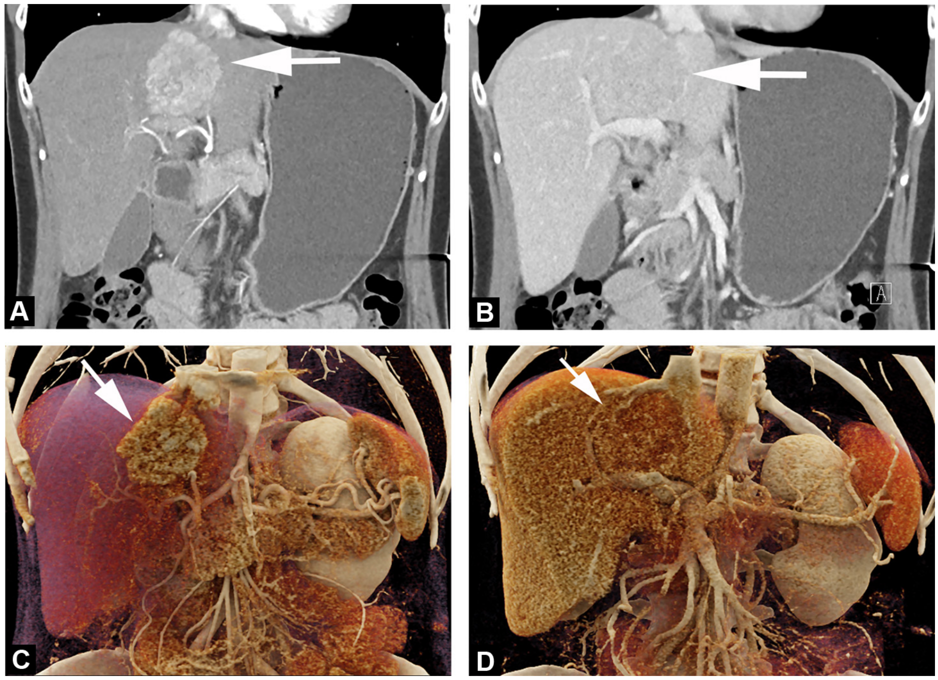

Figure 3. A 52-year-old woman with incidentally detected liver mass. A. Two-dimensional CT image obtained in the coronal plane during the arterial phase of enhancement shows an avidly homogeneously enhancing mass in the left medial section of the liver (segment 4) (arrow). B. CT image obtained in the coronal plane during the portal venous phase of enhancement with cinematic rendering shows that the mass becomes isoattenuating relative to background liver on venous phase (arrow), compatible with focal nodular hyperplasia. C and D. CT images obtained in the coronal plane during the arterial (C) and portal venous phase (D) of enhancement with cinematic rendering. Cinematic rendering images increase the conspicuity of the mass by varying the window level and width settings.

Hemangioma

Hemangioma is the most common benign liver neoplasm, with prevalence of up to 20% in the general population [10]. Pathologically, hemangiomas are composed of many endothelium-lined vascular spaces separated by fibrous septa and they derive their vascular supply from the hepatic artery [11]. Classically, hemangiomas show peripheral discontinuous globular enhancement during the arterial phase with progressive centripetal enhancement on the venous phase [11,12]. CR can accentuate this enhancement pattern by highlighting the peripheral nodular enhancement (Figs. 1 and 2). The hypoenhancing portion of the mass can be rendered translucent by altering the window settings to illustrate the texture of peripheral puddling of contrast (Fig. 2).

Focal nodular hyperplasia

Focal nodular hyperplasia is the second most common benign solid liver lesion and is more common in women. It is classically described as a benign tumor-like hyperplastic nodule with a central stellate scar containing malformed vascular structures and radiating fibrous septa [13]. It typically appears as an unencapsulated homogeneously hyperenhancing mass on arterial phase. It becomes isoenhancing or slightly hyperenhancing during portal venous or delay phase images, which can make it difficult to detect on these phases [14]. CR can vary the window level and width settings to increase the conspicuity of focal nodular hyperplasia on both arterial and venous phases (Fig. 3).

Liver abscess

Pyogenic abscess can be caused by disseminated hematogenous infection, ascending cholangitis, or superinfection of necrotic tissue [15]. It typically appears as a well-defined hypoenhancing mass, with variable degree of internal septations and enhancement. Internal gas is uncommonly seen [15—17]. CR can improve depth perception, which may improve appreciation of the thick peripherally enhancing capsule and any internal septations (Fig. 4). Recognition of its complex cystic nature helps differentiate an abscess from a simple cyst. Appreciation of any complex internal septations or debris is also helpful in predicting whether the abscess will be readily drainable via percutaneous approach.

Hepatocellular carcinoma

Hepatocellular carcinoma (HCC) is the most common primary liver malignancy and the risk of HCC is increased in patients with cirrhosis, hepatitis B, and hepatitis C infection [18—23]. HCC nodules induce angiogenesis of small arterial feeders and decrease the blood flow through the portal tracts (which contain portal veins and normal hepatic arteries). This results in a net increase in arterial flow in the HCC nodules, and accounts for the characteristic hyperenhancement on arterial phase and ''washout'' on portal venous

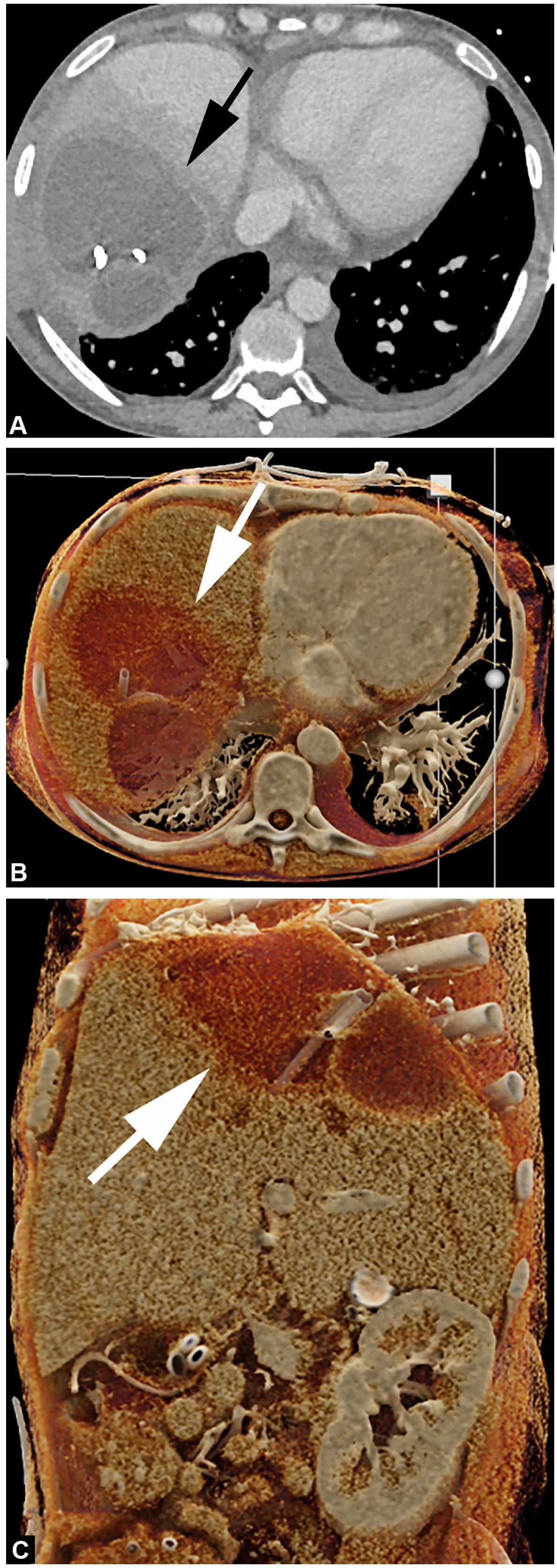

Figure 4. A 49-year-old woman with history of liver abscess. A. Two-dimensional CT image obtained in the axial plane during the portal venous phase shows a loculated cystic mass within the right liver (arrow). B and C. CT images obtained in the axial (B) and coronal (C) plane during the portal venous phase of enhancement with cinematic rendering improve visualization of the thick enhancing wall of the abscess (arrow). Of note, percutaneously placed drain is visible, so that CT images with cinematic rendering help confirm accurate drain placement.

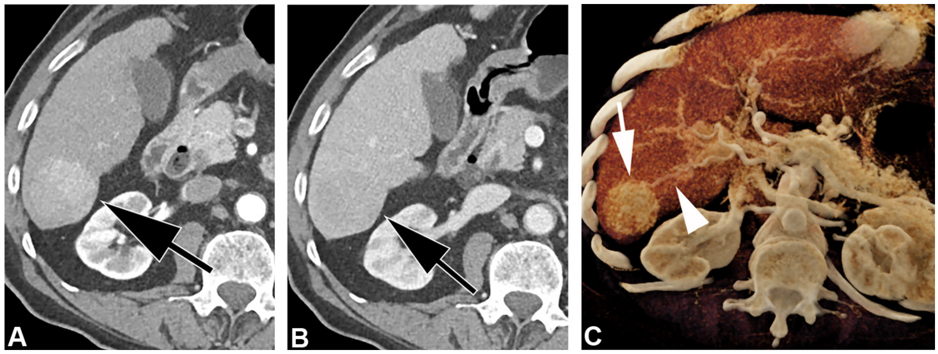

Figure 5. A 79-year-old man with history of hepatitis B and hepatitis C with hepatocellular carcinoma. A. Two-dimensional CT image obtained in the axial plane during the arterial phase of enhancement shows a subtle, hypervascular mass (arrow) in the lateral section of the right liver. B. Two-dimensional CT image obtained in the axial plane during the venous phase of enhancement shows characteristic washout (arrow) compatible with hepatocellular carcinoma. C. CT image obtained in the axial plane during the arterial phase of enhancement with cinematic rendering can increase the conspicuity of the liver mass (arrow) and the feeding artery (arrowhead).

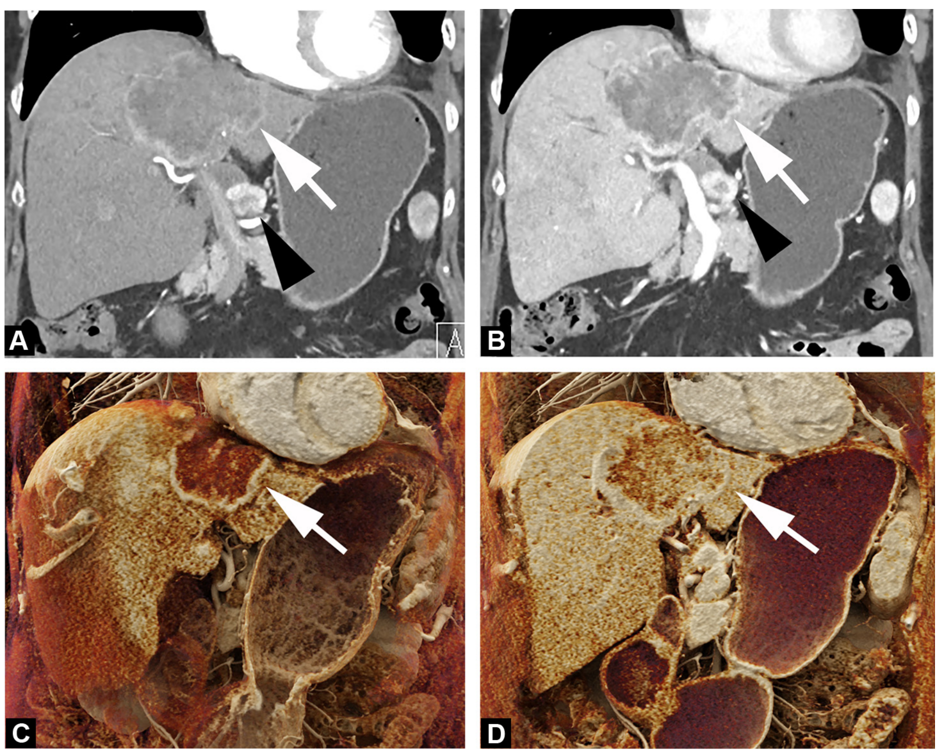

Figure 6. A 75-year-old woman with biopsy proven cholangiocarcinoma. A & B. Two-dimensional CT images obtained in the coronal plane during the arterial (A) and portal venous phase (B) of enhancement show a heterogeneously enhancing mass (arrow) with progressive delayed enhancement (arrow) within the left liver. C & D. CT images obtained in the coronal plane during the arterial (C) and portal venous phase (D) of enhancement with cinematic rendering can accentuate the heterogeneous internal enhancement (arrow) on both arterial and venous phases, an important feature in distinguishing malignant from benign liver masses.

phase [18,20–23]. The dynamic window display of CR can increase the conspicuity of a subtle hypervascular HCC and highlight the feeding arteries (Fig. 5). Improved appreciation of the feeding vessels has the potential to improve preoperative planning for chemoembolization.

Cholangiocarcinoma

Intrahepatic cholangiocarcinoma is the second most common liver malignancy and accounts for 10–20% of all primary liver tumors [24,25]. Cholangiocarcinoma can exhibit a

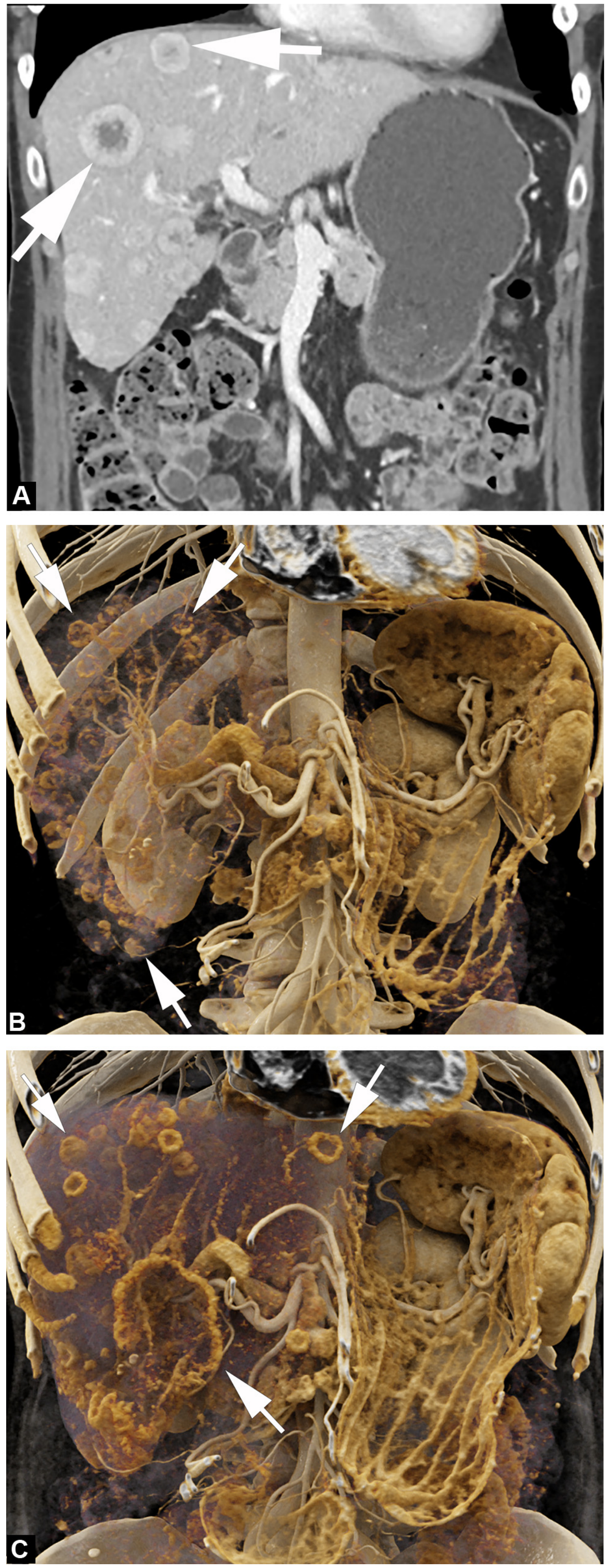

Figure 7. A 61-year-old woman with metastatic cholangiocarcinoma. A. Two-dimensional CT image obtained in the coronal plane during the portal venous phase of enhancement shows multiple enhancing liver masses with target appearance (arrows). B & C. CT images obtained in the coronal plane during the portal venous phase of enhancement with cinematic rendering can render the background liver translucent to highlight the global disease burden (arrows).

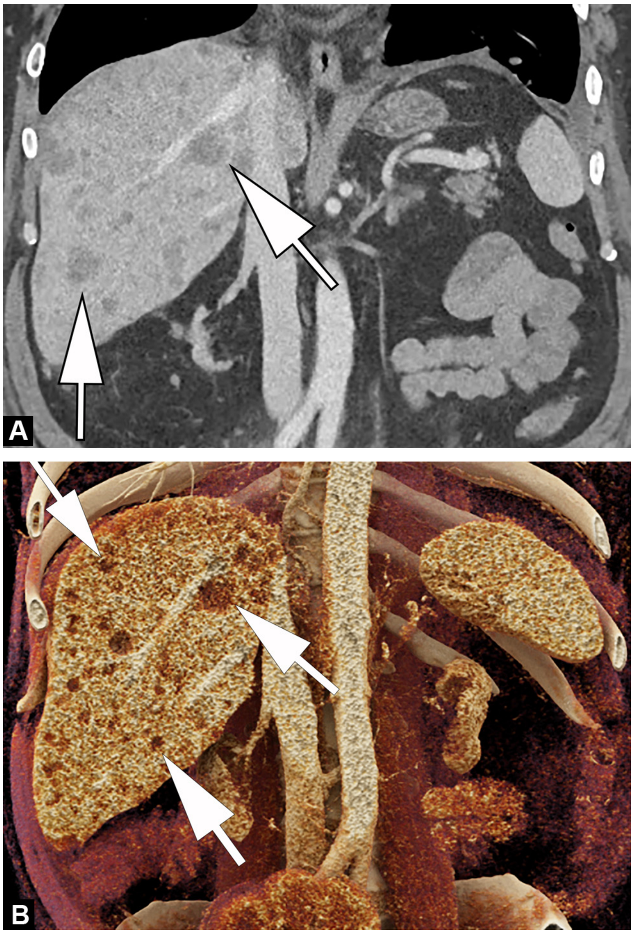

Figure 8. A 45-year-old man with history of metastatic head and neck squamous cell carcinoma. A. Two-dimensional CT image obtained in the coronal plane during the portal venous phase of enhancement shows numerous hypoenhancing liver lesions (arrows), compatible with metastatic disease. B. CT image obtained in the coronal plane during the portal venous phase of enhancement with cinematic rendering can increase tissue contrast and increase the conspicuity of these metastatic lesions (arrows).

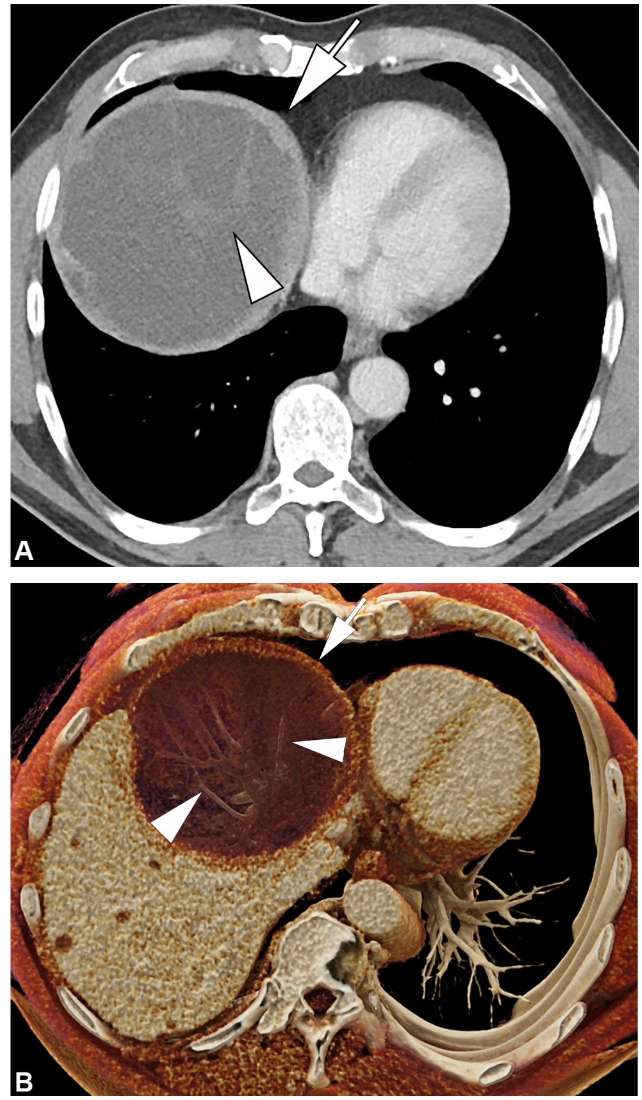

Figure 9. A 58-year-old man with history of metastatic gastrointestinal stromal tumor. A. Two-dimensional CT image obtained in the axial plane during the portal venous phase of enhancement shows a cystic mass (arrow) with multiple subtle internal septations (arrowhead). B. CT image obtained in the axial plane during the portal venous phase of enhancement with cinematic rendering can improve depth perception and appreciation of the subtle internal septations (arrowheads) in the complex cystic mass (arrow).

variety of growth patterns including focal mass lesion, periductal infiltration, and intraductal growth patterns [24,26]. As opposed to HCC, which is typically hypervascular on arterial phase, cholangiocarcinoma typically shows irregular peripheral enhancement with gradual centripetal enhancement [24,26]. The CR display can highlight the heterogeneous delayed enhancement pattern (Fig. 6), which is important in differentiating cholangiocarcinoma from HCC (Fig. 5) and benign liver masses (Figs. 1—3).

Metastatic disease

The dynamic window display of CR can be modified to highlight the disease burden of both hypervascular and hypovascular metastases. The background liver can be rendered translucent to highlight the innumerable hypervascular cholangiocarcinoma metastases throughout the liver (Fig. 7). In cases of hypovascular metastases, the CR display increases depth perception and can increase the conspicuity of small hypovascular metastases (Fig. 8). These photorealistic renderings can facilitate communication with referring clinicians and patients regarding the global disease burden. The increased depth perception with CR can improve appreciation of internal architecture of the metastatic lesions (Fig. 9), which is important in differentiating metastatic disease from benign liver lesions. The increased depth perception can also improve visualization of local tumor extension (Fig. 10) and delineate the relationship between the mass and critical anatomic structures (e.g., vessels, bile ducts, adjacent organs), which may be helpful for preoperative planning.

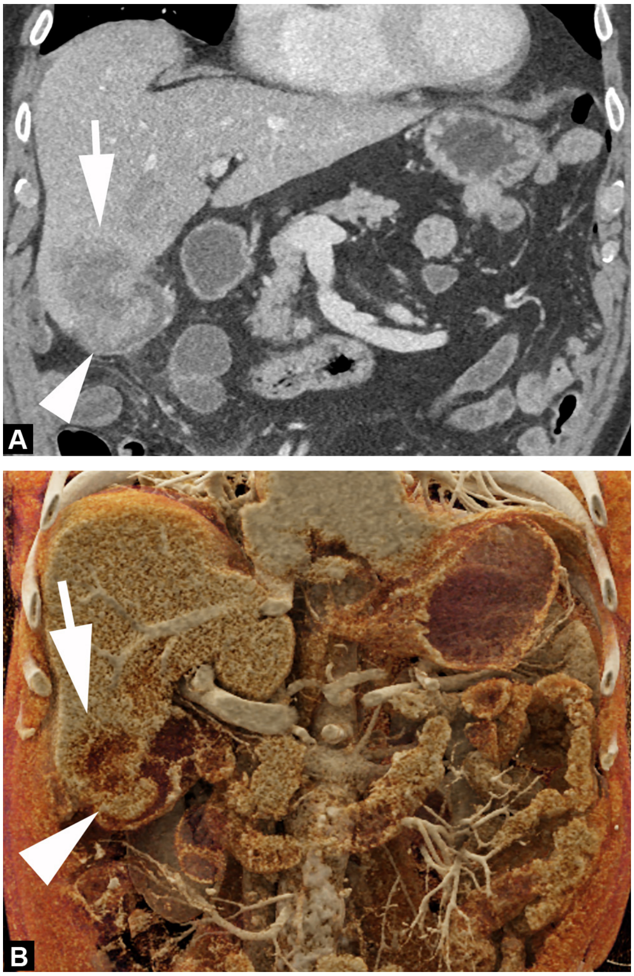

Figure 10. A 79-year-old man with history of metastatic colon cancer. A. Two-dimensional CT image obtained in the coronal plane during the portal venous phase of enhancement shows a heterogeneously enhancing liver metastasis in the right liver (arrow) with direct invasion into the gallbladder (arrowhead). B. CT image obtained in the coronal plane during the portal venous phase of enhancement with cinematic rendering can improve depth perception and increase appreciation of tumor invasion (arrow) into the gallbladder lumen (arrowhead).

Conclusion

CR shows promise in the evaluation of focal liver masses. CR can potentially improve the detection of subtle liver lesions and improve recognition of enhancement pattern and internal architecture, which are important features in the differential diagnosis. CR can also improve the appreciation of local tumor extension and global disease burden, which may be helpful in pretreatment planning. These preliminary observations show potential application of CR in the evaluation of focal liver masses, which will require validation in future studies.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

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Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

Disclosure of interest

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The other authors declare that they have no competing interest.

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