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Virtual cavernoscopy: a novel diagnostic tool for use in the corpus cavernosal lumen in patients with erectile dysfunction

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Study Type – Diagnostic (case series)
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What's known on the subject? and What does the study add?
In visualizing the artery in patients with ED, digital subtraction angiography, CT angiography and color Doppler ultrasonography has been performed.

There were difficulties with the previous methods in visualizing the stenotic lesion, or parts beyond the obstruction of the artery. Virtual cavernoscopy can visualize an artery independently of blood flow. We therefore believe that this new imaging technology will contribute to better ED practice.

OBJECTIVE

- To evaluate virtual cavernoscopy as a diagnostic tool in erectile dysfunction.

PATIENTS AND METHODS

- Forty patients who visited our hospital for investigation of erectile dysfunction underwent cavernosography using three-dimensional (3D)-computed tomography (CT).
- Virtual cavernoscopic images were reconstructed from 3D-CT data.

RESULTS

- Virtual cavernoscopic images were obtained from all patients.
- Virtual cavernoscopy visualized the corpus cavernosal lumen surrounded by the tunica albuginea, the septum of the cavernosum, the outlets of the veins, and cavernous arteries.
- The visualization of each structure depended on the window level (WL). At WL 400, the virtual cavernoscopy visualized only a fibrous structure. At this WL, the internal view of the corpus cavernosum was expressed as a hollow space. At WL 1600, the virtual cavernoscopy visualized the cavernous artery as a filling defect.
- Out of 80 lumens in the 40 subjects, arteries in 14 lumens were detected by both virtual cavernoscopy and CT angiography, while arteries in 50 lumens were detected only by virtual cavernoscopy. Arteries in two lumens could not be visualized by either method and those in 14 lumens were visualized only by CT angiography.

CONCLUSION

- In visualizing the artery, conventional imaging techniques depend on blood flow, whereas using virtual cavernoscopy an artery can be visualized independently of blood flow. Virtual cavernoscopy is unique in this regard and we therefore believe that this new imaging technology will contribute to better ED practice.

KEYWORDS

virtual cavernoscopy, virtual endoscopy, ED, CT angiography, 3D-CT cavernosography, DICC

INTRODUCTION

Recent developments in digital technology have allowed us to reconstruct virtual endoscopic images using cross-sectional CT or MRI data [1–3]. We used this technique to obtain virtual endoscopic images of the corpus cavernosum. The study of virtual endoscopy was begun in the field of colonoscopy [4] then broadened to other organs, such as the bronchus [5], bladder [6], ureter [7] and pharynx [8]. Nowadays, virtual endoscopic technology is used not only for clinical diagnosis, but also for anatomical studies and for training in actual endoscopy [9].

The range of applications for this virtual endoscopic technique has until now been limited to hollow organs; a virtual endoscope was a substitute for an actual endoscope. The corpus cavernosum has no lumen, but we considered that a virtual endoscopic technique might also be useful in the clinical area of erectile dysfunction (ED), and tried applying virtual endoscopy to the corpus cavernosum. Our initial results revealed the potential significance of this novel diagnostic tool in ED practice.

PATIENTS AND METHODS

In the present study, 40 patients with ED underwent cavernosography using three-

FIG. 1. ***A****, 3D cavernosographic image. The corpus cavernosum is filled with a contrast medium.* ***B****, A cross-sectional view of the area indicated by an arrow in (****A****). This image was reconstructed by rejecting all voxels with a density greater than the Hounsfield units of contrast medium and then generating an endoluminal view. A virtual cavernoscopic image is thus obtained (****C****). The white arrow and red arrows in C indicate the septum of the corpus cavernosum and cavernous arteries, respectively.*

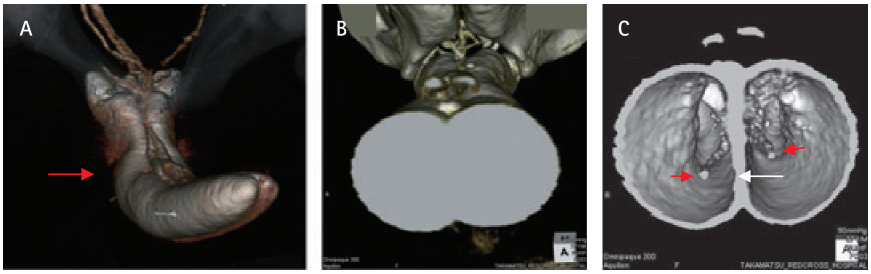


*FIG. 2. Virtual cavernoscopic images: (****A****) a distant view and (****B****) a close-up view from the distal end of the corpus cavernosum to the furcation of the crus. The upper part of the image is the dorsal side and the lower part is the urethral side. The white arrow indicates the septum of the corpus cavernosum and the red arrow indicates the right crus.*

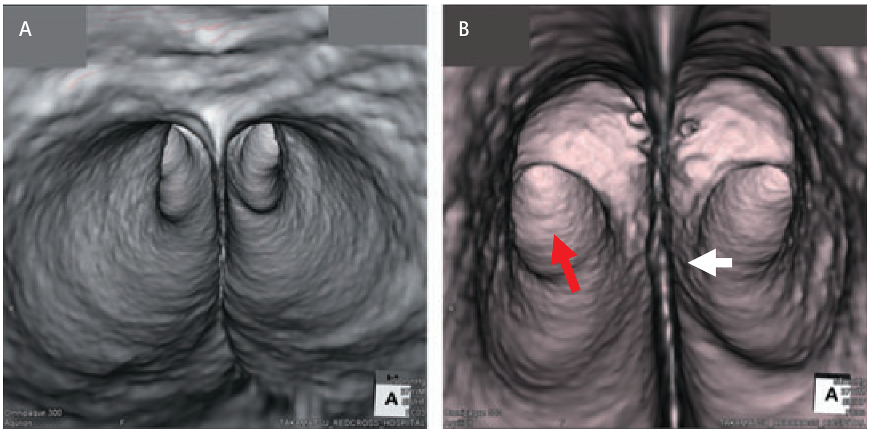


FIG. 3. Virtual image view from the mid portion of the corpus cavernosum to the distal end. The red arrow indicates communication channels between the corpus cavernosum and the glans.

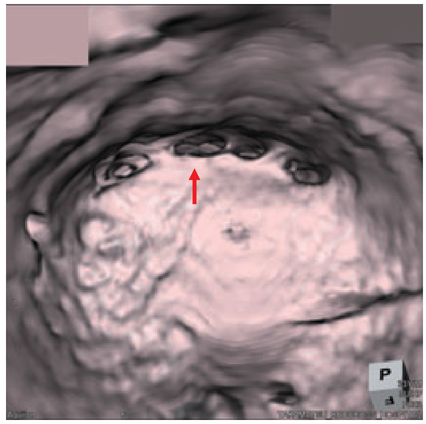
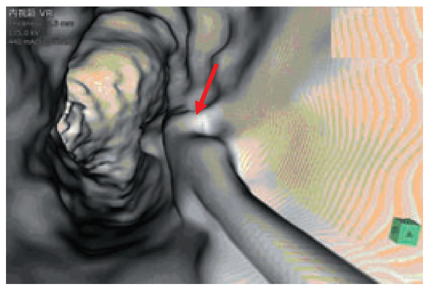


FIG. 4. Penile cavernous artery. The right cavernous artery is visualized in the right cavernosal lumen. The red arrow indicates the entrance point of the cavernous artery.



dimensional (3D)-CT. Their median (range) age was 34 (18–68) years. Virtual cavernoscopic images were reconstructed from 3D-CT data. Cavernosography was carried out according to a standard procedure, as follows. After obtaining written informed consent, we administered 60 mg papaverine hydrochloride into the penis through a 21G butterfly needle and recorded the intracavernous pressure for 10 min. After this, a 19G butterfly needle was inserted into the opposite corpus cavernosum for infusion. The infusion fluid was a mixture of 100 mL normal saline, 100 mL non-ionic contrast medium (iohexol) and 1 mL heparin. Infusion was carried out automatically with a CavroPump R (Life-Tec, Inc, Gaithersburg, MD, USA). To protect the gonads from irradiation, a cylindrical protector was used. Cavernosography was then performed at 90 mmHg intracavernous pressure, using a multi-slice CT scan system (Aquilion 64, Toshiba Medical, Tochigi, Japan).

Computer software was then used to reconstruct 3D images (Aquarius Net Station, ver. 2). The scanning parameters were as follows: slice thickness, 0.5 mm; pitch, 41.0; and scan speed, 0.5 s/rot. Commercially available software, the Ziostation System 1000 (version 1.17 t), and the volume analyser Synapse Vincent (Fujifilm Medical, Tokyo, Japan), were used to reconstruct a virtual endoscopic image from the 3D-CT data (Fig. 1). Findings from the virtual cavernoscopy were then compared with those obtained by angiography.

RESULTS

In all cases, we were able to reconstruct virtual cavernoscopic images from 3D-CT data. We were able to move the virtual endoscope backwards and forwards on the computer display and tilt it freely within the corpus cavernosum. It was also possible to visualize structures inside the corpus cavernosum, e.g. the septum, the penile cavernous arteries and the vein outlets. The visualization of each structure depended on the window level (WL). At WL 400, the virtual cavernoscopy visualized only a fibrous structure, with the internal view of the corpus cavernosum expressed as a hollow space (Figs 2,3). At WL 1600, the virtual cavernoscopy visualized the cavernous artery as a filling defect (Fig. 4). In most cases there was one cavernous artery in each corpus cavernosum, and some showed variation (Fig. 5,6). Images of the penetration branches from the dorsal artery were also obtained (Fig. 7).

FIG. 5. Image showing two arteries in the left corpus cavernosum. The red arrow points to the cavernous artery, the white arrow shows the penetrating branch from the circumflex artery.

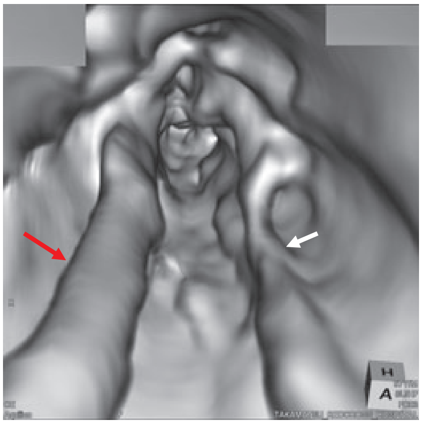
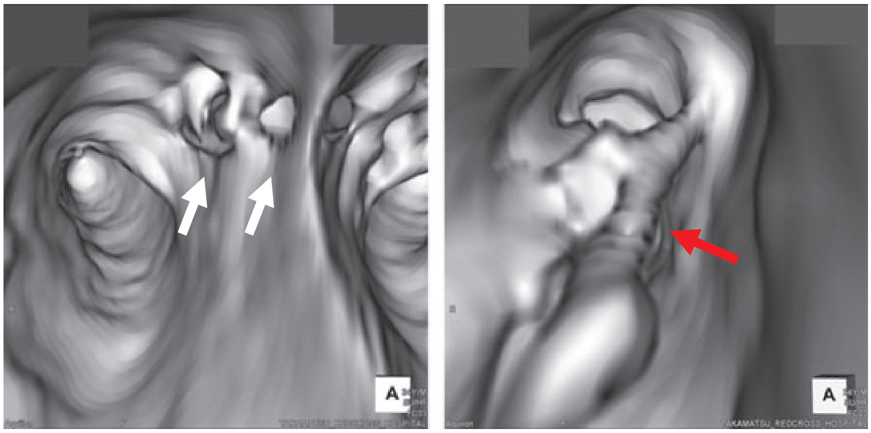


FIG. 8. Outlets of the right cavernous veins (white arrows) and the right cavernous artery (red arrow). These images show the right crus of the same patient from the same angle, revealing that the cavernous vein and cavernous artery run adjacent to each other.



WL 650 WL 1600

FIG. 6. Image showing the penetrating branch from the right penile dorsal artery (red arrows) branching out to the left side over the septum (white arrow).

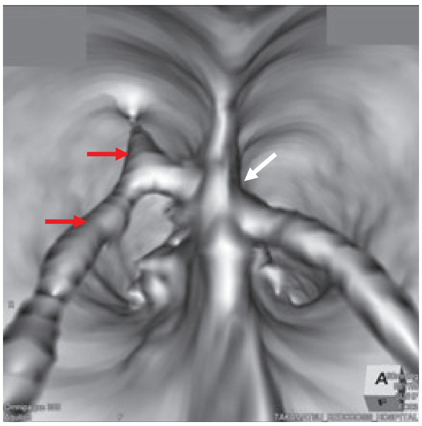


FIG. 9. Outlets of the crural veins, indicated by blue arrows.

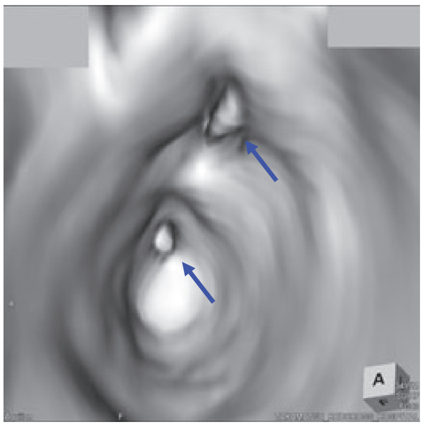
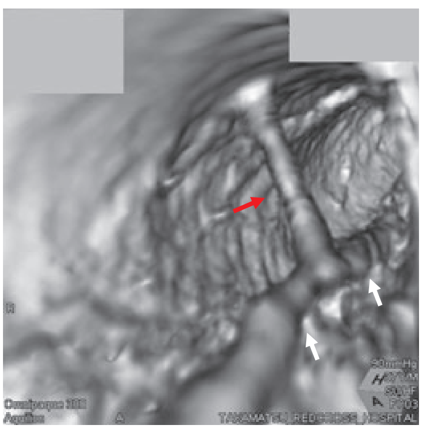


TABLE 1. Comparison of virtual cavernoscopy and CT angiography in visualizing the cavernous artery

(n = 80)	
CT angiography only	2
Virtual cavernoscopy only	50
Visualized by both methods	14
Not visualized by both methods	14

FIG. 7. Image showing the penetrating branch from the penile dorsal artery (red arrow) flowing into the penile cavernous artery (white arrows).



The outlets of the corpus cavernosal lumen were visualized at WL 650. We could pinpoint all the origins of the venous leakages, such as the deep dorsal vein, the cavernous vein, the crural vein, and the circumflex vein. The deep dorsal vein was observed as a space lined on the dorsal part of the corpus cavernosum and we could also see inside it. The route flowing out into the glans from the corpus cavernosum was also observed directly (Fig. 3). The cavernous vein, the most common drainage vein, originates from the coapted part where the right and left corpus cavernosum join together (Fig. 8). Specifically the cavernous veins flow out from proximal dorsal points at the furcation of the crus. This area is also the place where the artery comes in, and virtual cavernoscopy showed that the cavernous vein ran adjacent to the cavernous artery. Crural veins were observed in the dorsal part of the crus (Fig. 9). Crural veins originated from the midpoint of the crus or at a more distal point.

Virtual cavernoscopy showed cavernous arteries in 64/80 corpus cavernosal lumen. Virtual carvernoscopy detected 50 arteries that were undetected using CT angiography. Conversely, two arteries were detected with CT angiography, but not with virtual cavernoscopy (Table 1).

DISCUSSION

Endoscopy now plays a significant role in clinical practice, including urology where cystoscopy, ureteroscopy and pyeloscopy are essential. The study of virtual endoscopy began in response to a demand for less invasive inspection [4] and the usefulness of virtual cystoscopy, virtual colonoscopy and virtual bronchoscopy have been reported

[4–6]. Virtual endoscopy was developed as a substitute for an actual endoscope, but virtual cavernoscopy is different in that the corpus cavernosum contains cavernous tissue and vessels and is not a hollow organ. Cavernous tissue has a fibrous skeleton consisting of elastic fibre, collagen fibre and cavernous smooth muscle. The virtual cavernoscopic image, though reconstructed from 3D image data, is not a simple reversal of the 3D image. While virtual angioscopy merely shows internal surfaces of the vessel walls, virtual cavernoscopy can visualize not only the internal surface, but also the internal structures of the corpus cavernosum such as the septum, the cavernous artery or venous outlet.

Visualization of the cavernous artery is one of the most promising characteristics of this technique. During this examination, the corpus cavernosum is filled with a contrast medium, while the artery contains no contrast medium. A virtual cavernoscopy, therefore, visualizes the artery as the reversed image of the filling defect. Accordingly, blood flow does not affect the quality of the visualization of the artery. In other words, arteries can be visualized even if blood flow is significantly decreased or even completely stopped. Digital subtraction angiography, CT angiography and colour Doppler ultrasonography can detect an artery with blood flow [2,10], but these methods cannot visualize arteries with decreased blood flow, or arteries without blood flow, very well. Vascular imaging is more important in patients with decreased arterial blood flow than for those with normal blood flow. There were difficulties with previous methods in visualizing the stenotic lesion itself, or parts beyond the obstruction. Virtual cavernoscopy can visualize the external surface of the artery. In our study, 50 cases of cavernous arteries were detected with virtual cavernoscopy, but undetected with CT angiography. Ascertaining the existence of a cavernous artery or penetrating branch of a penile dorsal artery before arterial revascularization is useful for selecting the appropriate reconstruction method. Cavernosography is performed using 3D-CT to evaluate veno-occlusive function in patients who are about to undergo penile revascularization and these patients do not have to receive any additional invasive inspection to obtain virtual cavernoscopic images. Virtual cavernoscopy makes 3D-CT useful in the evaluation not only of the artery, but also of venous leakages.

Diagnosis of venous leakages from the corpus cavernosum has continued to be carried out using conventional X-ray [11,12], however, as the cavernous vein and crural vein are often overlapped by pelvic bone or cavernous bodies, diagnosis of the origin of these veins is often problematic. Although cavernosography using 3D-CT can visualize drainage veins clearly from various angles, there are cases in which accurate evaluation of the origin of venous leakages is difficult, if the outflow is excessive. As virtual cavernoscopy visualizes the corpus cavernosum from the inside, it can show the origin of the drainage veins with greater ease and precision. We can evaluate the venous leakage more accurately by combining virtual cavernoscopy with 3D-CT. A recent study shows that recurrences of ED after surgery have been attributable to the omission of ligation of the corresponding veins [13]. We believe virtual cavernoscopy will contribute to an improvement in the results for venous ligation surgery.

With regard to the technical aspects of virtual endoscopy, one of the issues which requires improvement is the filling of contrast medium in the corpus cavernosum. Because this examination depicts the area filled with contrast medium as a reverse image, a fine image cannot be obtained when the corpus cavernosum is insufficiently filled with contrast medium. In this study, 16 cases were undetected with virtual cavernoscopy owing to this phenomenon. Further consideration is necessary concerning methods of achieving sufficient contrast medium filling. It is also necessary to consider imaging conditions to guarantee minimum radiation exposure from the CT; it is essential to prevent exposure to the gonads in young patients.

Up until now there has been no examination method like virtual cavernoscopy, therefore, we hope that this novel imaging technology will play an important role in ED practice in combination with other imaging methods from now on.

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CONFLICT OF INTEREST

None declared.

REFERENCES

1 **Kay CL, Evangelou HA.** A review of the technical and clinical aspects of virtual endoscopy. *Endoscopy* 1996; **28**: 768–75

2 **Kawanishi Y, Lee KS, Kimura K, Kojima K, Yamamoto A, Numata A.** Feasibility of multi-slice computed tomography in the diagnosis of arteriogenic erectile dysfunction. *BJU Int* 2001; **88**: 390–5

3 **John H, Kacl GM, Lehmann K, Debatin JF, Hauri D.** Clinical value of pelvic and penile magnetic resonance angiography in preoperative evaluation of penile revascularization. *Int J Impot Res* 1999; **11**: 83–6

4 **Vining DJ, Gelfand DW, Bechtold RE *et al.*** Technical feasibility of colon imaging with helical CT and virtual reality. *AJR Am J Roentgenol* 1994; **162** (Suppl.): 104

5 **Buthiau D, Antoine E, Piette JC, Nizri D, Baldeyrou P, Khayat D.** Virtual tracheo-bronchial endoscopy: educational and diagnostic value. *Surg Radiol Anat* 1996; **18**: 125–31

6 **Bernhardt TM, Rapp-Bernhardt U.** Virtual cystoscopy of the bladder based on CT and MRI data. *Abdom Imaging* 2001; **26**: 325–32

7 **Battista G, Sassi C, Schiavina R *et al.*** Computerized tomography virtual endoscopy in evaluation of upper urinary tract tumors: initial experience. *Abdom Imaging* 2009; **34**: 107–12

8 **Rodenwaldt J, Kopka L, Roedel R, Margas A, Grabbe E.** 3D virtual endoscopy of the upper airway: optimization of the scan parameters in a cadaver phantom and clinical assessment. *J Comput Assist Tomogr* 1997; **21**: 405–11

9 **Gessner CE, Jowell PS, Baillie J.** Novel methods for endoscopic training. *Gastrointest Endosc Clin N Am* 1995; **5**: 323–36

10 **Aversa A, Sarteschi LM.** The role of penile color-duplex ultrasound for the evaluation of erectile dysfunction. *J Sex Med* 2007; **4**: 1437–47

11 **Wespes E, Delcour C, Struyven J, Schulman CC.** Cavernometry-cavernography: its role in organic

impotence. *Eur Urol* 1984; **10**: 229–32

12 **Lewis RW, Puyau FA, Bell DP.** Another surgical approach for vasculogenic impotence. *J Urol* 1986; **136**: 1210–2

13 **Chen SC, Hsieh CH, Hsu GL *et al.*** The progression of the penile vein: could it be recurrent? *J Androl* 2005; **26**: 53–60

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Abbreviations: **3D**, three-dimensional; **ED**, erectile dysfunction; **WL**, window level.