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Three-dimensional CT cavernosography: reconsidering venous ligation surgery on the basis of the modern technology

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What's known on the subject? and What does the study add?
Venous ligation surgery has been conducted as a symptomatic treatment, but the effective rate of this surgery was insufficient. We thought that one of the reasons for the low effective rate of this surgery was insufficient for the diagnostic modality. We confirmed that 3D cavernosography was, in comparison with conventional cavernosography, higher in diagnosis precision.

OBJECTIVE

- To examine the feasibility of three-dimensional (3D) CT cavernosography in the diagnosis of corporal veno-occlusive dysfunction.

PATIENTS AND METHODS

- The subjects were 55 patients who had failed to respond to phosphodiesterase type 5 inhibitors. We performed pharmacodynamic infusion cavernosometry and cavernosography, using 60 mg papaverine hydrochloride.
- Cavernosography was performed at 90 mmHg intracavernous pressure, using a multi-slice CT scan system. The 3D images were reconstructed using AQUARIUS NET STATION, ver.2 computer software.
- For comparison with conventional cavernosography, maximum intensity projection (MIP) images were used. A flow of 20 mL/min or being more capable of maintaining 90 mmHg of intracavernous pressure indicated veno-occlusive dysfunction.

RESULTS

- Forty-five of the 55 patients were diagnosed with corporal veno-occlusive dysfunction. 3D-CT cavernosography revealed drainage veins in all 45 cases, including cavernous veins, dorsal veins, crural veins and other emissary veins.
- Compared with 3D-CT cavernosography, observing cavernous veins and the proximal part of the deep dorsal veins using MIP imaging was especially difficult because the origins of the penile veins are often behind the pelvic bone or cavernous body.
- Of the patients who seemingly had leakage via the deep dorsal vein, 80.6% did not in fact have leakage via this vein, but had other leakages. The image resolution of 3D-CT cavernosography was significantly higher than that of MIP.

CONCLUSION

- 3D-CT cavernosography can provide high-resolution images of venous drainage from any angle. We conclude that the images obtained by 3D-CT cavernosography are very helpful for both the diagnosis of corporal veno-occlusive dysfunction and the anatomical study of the human penile venous system.

KEYWORDS

three-dimensional CT, cavernosography, corporal veno-occlusive dysfunction, venous leakage

INTRODUCTION

Virag [1] first reported papaverine test as a clinical examination for erectile dysfunction in 1982, and a movement to diagnose erectile function from the viewpoint of hemodynamic events began. Wespes *et al.* [2] showed that not only the arterial system, but also the venous system is important for normal erectile function and they reported erectile dysfunction caused by venous system abnormalities. Although several types of venous surgeries that ligated the responsible penile veins were performed, the long-term outcome of all those surgeries was disappointing.

Even though Lewis *et al.* [3] tried to promote cavernosography through the use of cine-taped cavernosography, the diagnosis of the leak site continued to use conventional X-ray. However, because the veins were often overlapped by other veins, or by bone or cavernous body, we were not always able to obtain clear images of the origin of the veins, even when we used radioscopy or tried changing the angle of the X-ray beam or tilting the position of the patient. Diagnostic imaging has progressed remarkably so we can obtain high-resolution arterial images similar

FIG. 1. Three-dimensional cavernosography. The deep dorsal vein is visualized clearly at the body of corpus cavernosum (white arrow), however this vein is significantly narrowed at the base of the penis (white arrow). The cavernous veins originate in the adjacent area (red arrows).

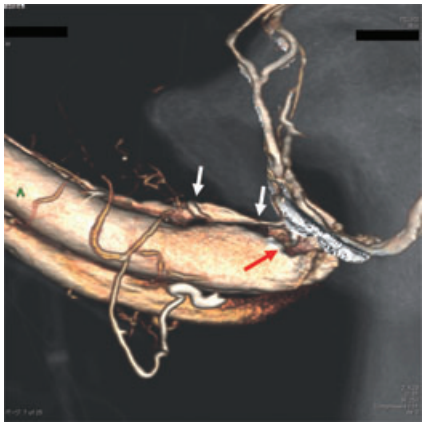


FIG. 2. Deep dorsal vein showed complete blocking at the base of the penis (white arrow).

FIG. 3. Deep dorsal vein and cavernous veins are also the responsible vessels. Deep dorsal vein: white arrow, cavernous veins: red arrows.

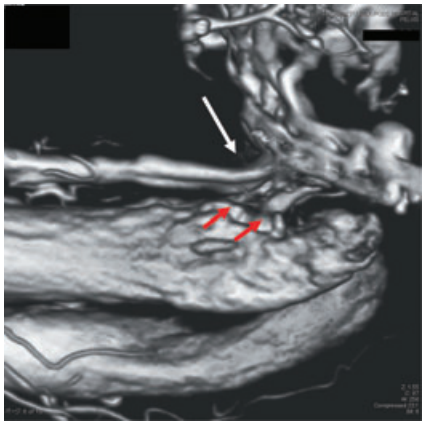


FIG. 4. The deep dorsal vein. The deep dorsal vein (white arrows) is the sole leak vein in this case.

to digital subtraction angiography with a CT scanner [4], and images of the venous system with an MRI scanner [5]. Furthermore, recent technological developments allow us to reconstruct three-dimensional (3D) images from cross-sectional image data. We performed 3D-CT cavernosography on patients who had previously failed to respond to medical therapy.

PATIENTS AND METHODS

The study subjects were 55 patients with erectile dysfunction who had earlier failed to respond to phosphodiesterase type 5 inhibitors. Their ages ranged between 17 and 77 years, median 40.5 years. After obtaining written informed consent, we performed pharmaco-dynamic infusion cavernosometry and cavernosography to evaluate corporal veno-occlusive function.

After laying the patient on a CT scanner bed, we inserted a 21-G butterfly needle in the corpus cavernosum and connected this to a pressure transducer. We recorded the patient's intracavernous pressure directly. After administering 60 mg papaverine hydrochloride into the penis through this needle, intracavernous pressure was recorded for 10 min. After this a 19-G butterfly needle was inserted in 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 automatic using a CavroPump R (Life-Tech, Inc., Stafford, TX, USA).

To protect the gonad from irradiation, a cylindrical protector was used in every case. Cavernosography was then performed at 90 mmHg intracavernous pressure, using a multi-slice CT scan system (Aquilion 64, Toshiba Medical, Ootawara City, Tochigi-ken, Japan). Computer software was used to reconstruct 3D images (AQUARIUS NET STATION, ver.2). For comparison with conventional cavernosography, maximum intensity projection (MIP) images were used. When the maintenance flow rate for 90 mmHg of intracavernous pressure was 20 mL/min or more, we diagnosed a patient as the veno-occlusive dysfunctional patient.

RESULTS

Forty-five of the 55 patients examined were diagnosed with corporal veno-occlusive dysfunction. 3D-CT cavernosography revealed drainage veins in all 45 cases, which included cavernous veins, dorsal veins, crural veins and other emissary veins. There was no complication related to the examination.

Thirty-one (68.9%) of these 45 patients showed deep dorsal veins at the distal part of the penis. However, 14 of these 31 showed a narrowing of the diameter of the deep dorsal vein at the base of the penis (Fig. 1) and another 11 cases showed complete blockage of the deep dorsal vein at the base of the penis (Fig. 2). That is, a total of 25 cases (80.6% of the deep dorsal vein cases) seemed to have significant leakage via the deep dorsal vein, but in fact, this was not so. In three cases the deep dorsal vein seemed to be the only responsible vessel but 3D-CT cavernosography revealed that cavernous veins were also responsible (Fig. 3). In only three cases, the deep dorsal vein was the sole leakage point (Fig. 4).

Our results showed that the cavernous vein was the most common drainage vein. It appeared in 33 (73.3%) of the 45 patients (Fig. 5). In patients who had undergone CT angiography, we could reconstruct fusion images that showed both arteries and cavernosography on one 3D image. According to these, cavernous veins ran adjacent to penile arteries (Fig. 6). By processing the data through the Ziostation System 1000 (version 1.17t) (Ziosoft, Redwood City, CA, USA) at the workstation, we could obtain virtual endoscopic images of the corpus cavernosum (Fig. 7). The virtual cavernoscope could reveal the origin of the drainage vessels more accurately.

Fifteen cases showed leakage via the crural veins. Compared to MIP imaging, 3D-CT

FIG. 5. Cavernous veins as the sole responsible leak veins.

FIG. 6. Cavernous veins. Fusion image of CT angiography and 3D-CT cavernosography. Cavernous veins run close to penile arteries.

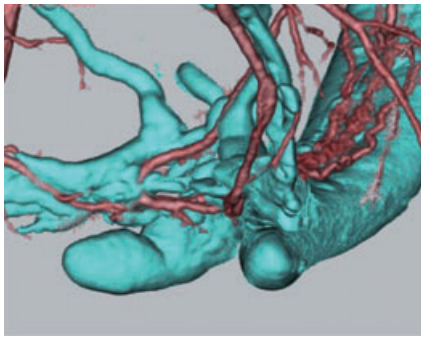
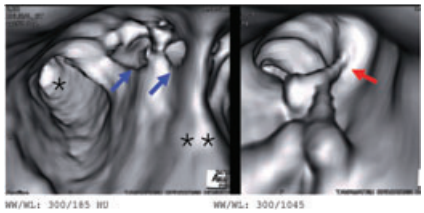


*FIG. 7. Virtual cavernoscopy. These two images are 'the virtual cavernoscopy' images of the right crural of the same patient with the same angle at a different window level. A virtual cavernoscope image shows that cavernous veins and cavernous artery run close together. *Right crus penis, **septum of corpus cavernosum, blue arrow: outlet of right cavernous veins; red arrow: right cavernous artery.*



cavernosography was more helpful in identifying crural veins (Fig. 8). Crural veins originated from the mid-point of the crus or at a more distal point in all but two cases

FIG. 8. Crural vein. Crural vein was well observed at an angle looking up a little from the lower area.

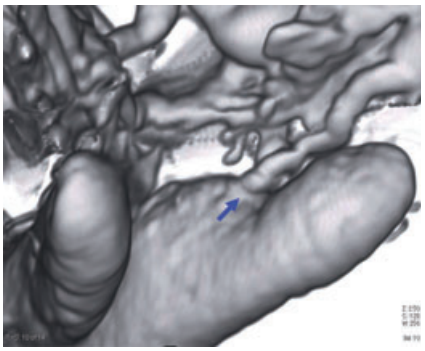
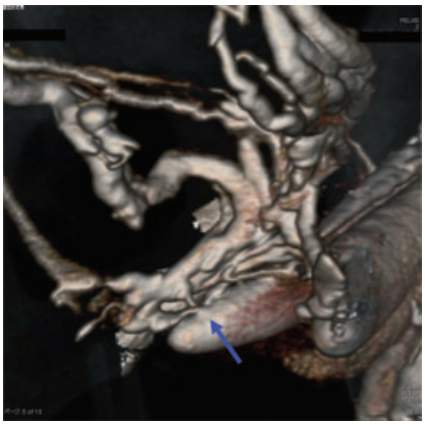


FIG. 9. Crural veins originated from the near end of the crus.

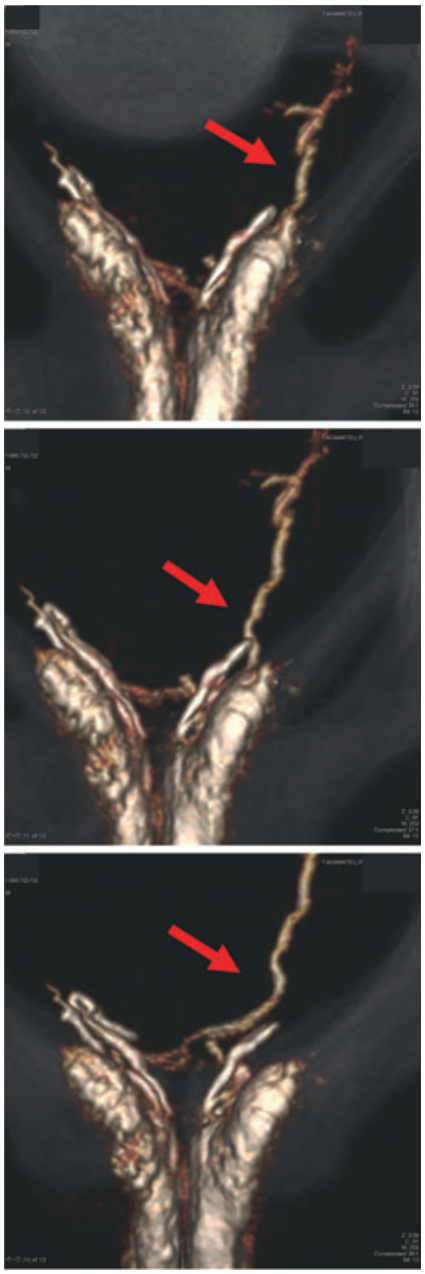


(Fig. 9). In four cases, taken only from the frontal view, the veins seemed to originate from the end of the crus, although the actual veins were quite different (Fig. 10). As 3D-CT cavernosography allows free rotation of the images, we could diagnose the origin of the drainage vessels accurately. Furthermore the fusion images showed that veins and arteries run adjacent to each other in this part of the penis (Fig. 11).

The 3D-CT cavernosography could reveal the origins of the emissary veins. Emissary veins were identified as significant drainage veins in 11 patients (Fig. 12).

Compared with 3D-CT cavernosography, identifying cavernous veins and the proximal part of the deep dorsal veins was much more difficult using MIP imaging, because the pelvic bone or cavernous bodies often overlapped the origin of the penile veins (Table 1).

FIG. 10. The origin of the veins is often difficult to diagnose by only one image. The seemingly cavernous vein (red arrow) is not the actual cavernous vein, but an obturator vein.



DISCUSSION

Despite analysis of factors deciding long-term results and of basic studies related to the mechanism of development of veno-occlusive dysfunction, venous ligation surgery did not prove to be a sufficient treatment [6–8]. After approval of the clinical use of

TABLE 1 Comparison between three-dimensional (3D) CT cavernosography and maximum intensity projection (MIP) image

Leak site	3D-CT images	MIP images
DDV, *n* (%)	31 (68.9)	36 (80.0)
Narrowing	14	
Blocked	11	
Patent	6	
Cavernous veins, *n* (%)	33 (73.3%)	7 (15.6)
Crural veins, *n* (%)	15 (33.3%)	23 (51.1)
Emissary or others, *n* (%)	11 (24.4)	9 (20.0)
Impossible to determine, *n* (%)	0	9 (20.0)

MIP image is used as analogous to conventional cavernosography.

phosphodiesterase-5 inhibitors, there were arguments about the necessity of invasive examinations and invasive treatment of erectile dysfunction [9–12]. Dynamic cavernosometry and cavernosography has become a rarely performed examination, which is performed only to negate the leakage before penile revascularization surgery [13]. However, in clinical practice, not all patients can have their problems resolved with the use of the phosphodiesterase-5 inhibitors. There are patients for whom phosphodiesterase-5 inhibitors are contraindicated, who fail to respond to all medicines, or who expect complete healing without medicines [14,15]. Furthermore, candidates for penile revascularization also often have corporal veno-occlusive dysfunction [16], and the surgical outcome for these patients with mixed vascular aetiologies is relatively unsatisfactory [17]. For such patients, the role of venous ligation surgery is significant.

Deep dorsal vein ligation surgery was first performed as an intervention for corporal veno-occlusive dysfunction [18,19]. However, using conventional cavernosography presented difficulties in visualizing the deep dorsal vein at the base of the penis. Our results showed that about 80% of the patients who seemingly had leakage via the deep dorsal vein did not in fact have leakage via this vein but had other leakages. In such cases, it is obvious that any kind of deep dorsal vein ligation surgery will prove ineffective. Among cases that had previously been diagnosed as corporal veno-occlusive dysfunction and had undergone deep dorsal vein ligation surgery, there might have been some cases which were actually not appropriate candidates for this surgery. These cases would therefore have caused errors in the evaluation of deep dorsal vein ligation surgery.

According to our observation, leakage through cavernous veins is most common. Lewis [20] had clearly pointed out the importance of ligation of cavernous veins. However, intervention specifically intended to ligate cavernous veins was not widely performed. Leakage via cavernous veins is certainly the most frequent, but depiction of these veins is difficult when using conventional cavernosography, and therefore there is a possibility that leakage via cavernous veins was not diagnosed accurately.

One-third of the patients in this study showed leakage through crural veins. According to 3D-CT cavernosography, in most cases, the original point of this vein is located near the bifurcation of the right and left corpus cavernosum rather than at the end of the crus of cavernosum. Therefore, there may have been cases that did not achieve the expected results after a conventional crural ligation surgery [21]. Some cases appear to have leakage via crural veins but actually have leakage via quite different veins (Fig. 10). It is presumed that in the previous execution of crural ligation surgery, there were cases that were also actually not appropriate candidates for this surgery.

The maximum intensity projection images of 3D-CT cavernosography are similar in principle and quality to conventional images so we compared 3D-CT cavernosography images with MIP images as a substitute for conventional cavernosography. The conformity between these two examinations was nominal. Considering the importance of cavernous veins, the lack of efficacy in conventional cavernosography would be a significant problem.

FIG. 11. The fusion image of the crural vein and arteries. They run in close proximity in this part of the penis also.

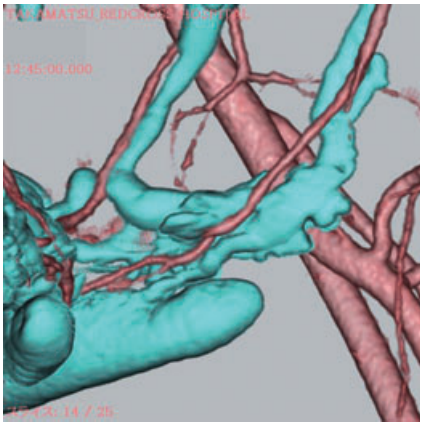


FIG. 12. Emissary veins by 3D-CT cavernosography. 3D-CT cavernosography can reveal the origins of emissary veins.

Having said this, there are some concerns while performing 3D-CT cavernosography. One of these is the movement of the bed during the examination into the gantry of the CT scanner. To conduct a safe examination, it is necessary to know in advance the range of movement of the bed so as to arrange sufficient lengths of infusion tubes and of the cables of the pressure transducer, and to fix everything securely to the drape.

Another concern is the difficulty in examining the patient. It is preferable to observe the patient beside the bed because in some patients the infusion rate is considerably high; however, to avoid radiation exposure, doctors, nurses and the radio technologist

must leave the room and depend on a remote viewing monitor for observation, albeit for a short period.

The problem in 3D-CT cavernosography compared with conventional cavernosography or MRI, would be radiation exposure to the patient. Using a cylindrical protector, the gonad is protected, but organs related to erectile function, including the neurovascular bundle, internal pudendal artery, accessory pudendal artery and corpus cavernosum, are exposed to X-ray radiation. The hazard related to X-ray exposure of these organs has been studied in radiation therapy for prostate cancer, and it has been concluded that the risk is not significant [22]. Even though the amount of X-ray exposure during a CT scan is significantly less than that during radiation therapy in prostate cancer, efforts to reduce radiation exposure are necessary. Studies in appropriate density of contrast medium and low-dose CT technique may help to resolve this problem.

After examining the 3D-CT cavernosography images, we have come to think that conventional cavernosography might not always correctly identify the site of the leak. Even though numbers were small, it was significant that after surgery some patients could maintain erectile function for a long period [3,7,23]. These patients might have been cases whose leak site was diagnosed correctly. In addition, the venous ligation surgery on patients whose leak site had been diagnosed precisely was effective [24–26]. Furthermore, a recent study [27] showed that the recurrence of erectile dysfunction was not the result of the re-development of veins, but ligation of the responding veins was omitted during the first surgery. These facts imply that correct diagnosis followed by tailor-made venous surgery will ameliorate the long-term outcome of venous ligation surgery.

CONFLICT OF INTEREST

None declared.

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Abbreviations: **3D**, three-dimensional; **MIP**, maximum intensity projection.