A New, Accurate and Conventional Five-point Method for Quantitative Evaluation of Ascites Using Plain Computed Tomography in Cancer Patients

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Background: To assess the exact response of the malignant ascites to the treatment, the objective measurement of the volume of ascites is essential. We have developed a simple method to measure the volume of ascites by using standard abdomino-pelvic computed tomography (CT). The aim of the study is to validate the accuracy of the measurements by comparing them with the standard volume calculation by using 3D-CT.

Methods: Twelve consecutive patients with cancer who had measurable ascites underwent 15 helical CT examinations. On conventional CT images, the thickness of ascites in centimeters was measured in three planes such as the bilateral subphrenic space (A and B), the bilateral paracolic space (C and D) and the pre-bladder space (E), and the average thickness: \((A + B + C + D + E)/5\) was then multiplied by the area of standard abdominal cavity in the anterior projection, that was assumed to be 1000 cm², to yield the volume of ascites: \((A + B + C + D + E) \times 200\) (ml). The volume of ascites was compared with the exact volume, that was obtained from 3D-CT with the volume rendering method.

Results: The volume of ascites measured by the present method and the volume rendering method ranged from 140 to 4040 ml and from 86 to 4279 ml, respectively. The correlation was statistically significant with a correlation coefficient of 0.956 \((P<0.01)\) using the Spearman’s rank correlation. In 13 examinations with the exact volume \(>300\) ml, the average ratio of the absolute difference in the volume was 12.9 – 13.9% as compared with 62.8 and 162.0% in two examinations with the exact volume \(<300\) ml.

Conclusion: The preliminary study indicated that the present five-point method using a conventional CT was accurate in patients with the volume of ascites \(>300\) ml. Because this procedure is simple and easy to perform, it should be feasible in many hospitals for the follow-up of ascites after treatment.

Key words: ascites – computed tomography – volume rendering method

INTRODUCTION

Clinical management of malignant ascites is of vital importance for cancer patients. Patients with various types of cancer of the upper gastrointestinal tract (stomach, pancreas, etc.) and ovarian cancer in the advanced stage often develop peritoneal dissemination of the tumors and ascites. Even if the treatment for primary disease is successful, development of ascites may give rise to serious complications, such as abdominal pain and an uneasy sense of fullness, vomiting, malnutrition and sometimes intestinal obstruction and renal dysfunction.

Treatment for these malignant ascites comprises two main types of therapies, surgical intervention and medication, such as administration of diuretics and chemotherapy for the malignancy itself.

Recent studies have found that chemotherapeutic regimens can reduce, or sometimes even eradicate, peritoneal disseminations and ascites in gastric cancer patients receiving S-1 and cisplatin (1,2) or S-1 alone (3,4). Another new anticancer drug, paclitaxel, has also been shown to eradicate malignant ascites when combined with 5-fluourouracil (5-FU) (5) or by means of

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direct intraperitoneal administration (6). Moreover, intraperitoneal injection of the immunotherapeutic agent OK-432 has been demonstrated to suppress malignant ascites from advanced gastric cancer (7,8). Finally, a phase II study was performed using a combination of methotrexate and 5-FU for malignant ascites (JCOG 9603) (9).

To determine the validity of the findings of these studies, the greatest challenge is how to evaluate the exact response of the malignant ascites to the various treatment strategies. Even in the most detailed study to date, the JCOG 9603, the response evaluation for ascites by means of abdominal computed tomography (CT) scan or ultrasonography was based on criteria determined by the investigators themselves. The significant flaw in their assessment is therefore that the criteria depend on the subjective and qualitative evaluation of the investigators.

Attempts to measure the response of ascites to a treatment more objectively usually involve estimating the amount of ascites by measuring the girth of the abdomen. Although this measurement is simple and very convenient, it is affected by various factors, such as intestinal content, muscle volume and amount of fatty tissue. These factors easily change, especially in the advanced stage of cancer, depending on the nutritional state of the patient.

The purpose of the present study is to develop a convenient and non-invasive, yet accurate, measurement of ascites. The simple and accurate method developed by us and reported here involves quantification of the volume of ascites by using standard whole abdomino-pelvic CT. The accuracy of our results was validated by comparing them with those obtained with the standard method for volume calculation, which uses surface rendering on 3D-CT. The latter procedure is commonly used to estimate the volume of parenchyma of organs such as the liver before and after transplantation (10). The procedure is applicable to the volume of ascites and is used as a reference standard in this study.

**PATIENTS AND METHODS**

Twelve consecutive patients (nine women and three men; age range: 36–82 years) with various types of cancer with ascites were examined with 15 whole abdominal CT scans from June to December 2003. The clinically determined cause of the ascites in all patients was peritonitis carcinomatosa derived from malignancy.

CT was performed with a Pro Speed SG or QXi (GE Medical Systems, Milwaukee, WI) CT scanning unit. Helical scans were obtained in 7 or 7.5 mm thick transverse sections at 7 or 7.5 mm intervals from the dome of the diaphragm to the symphysis pubis.

In order to calculate the volume of the ascites with our conventional method, the three planes of transverse CT images selected for measurement of the thickness of ascites were the bilateral subphrenic space, the bilateral paracolic space and the pre-bladder space. The thickness of ascites in the subphrenic space was calculated at the level where the superior mesenteric artery branches off from the aorta (Fig. 1). Two distances were measured, one between the inner surface of the right abdominal wall and the surface of the liver (A cm), and the other between the inner surface of the left abdominal wall and the surface of the spleen (B cm). On the CT image obtained at the level of the lower pole of the left kidney, the thickness of ascites in the paracolic space (Fig. 2) was determined by measuring the distance between the inner surface of the right abdominal wall and the center of the ascending colon when the ascending colon is located at the posterior pole of the right paracolic gutter or the vertical line through the posterior pole of the right paracolic gutter when the ascending colon is located off the posterior pole of the right paracolic gutter (C cm, Fig. 2), and the distance between the inner surface of the left abdominal wall and the center of the descending colon when the descending colon is located at the posterior pole (D cm, Fig. 2).

Figure 1. The thickness of ascites in the subphrenic space was calculated at the level of the superior mesenteric artery root. The distance from the inner surface of the right abdominal wall at the antero-posterior mid portion to the surface of the liver (A cm), and the distance from the inner surface of the left abdominal wall at the antero-posterior mid portion to the surface of the spleen (B cm) were measured.

Figure 2. On this CT image at the level of the lower pole of the left kidney, the thickness of ascites in the paracolic space was measured by determining the distance from the inner surface of the right abdominal wall at the antero-posterior mid portion to the vertical line through the posterior pole of the right paracolic gutter (C cm), and from the inner surface of the left abdominal wall to the vertical line through the posterior pole of the left paracolic gutter (D cm).
of the left paracolic gutter or the vertical line through the posterior pole of the left paracolic gutter (D cm, Fig. 2). The thickness of ascites in the pre-bladder space was calculated at the level of the femoral head (Fig. 3). The distance between the inner surface of the anterior abdominal wall and the line though the bilateral femoral arteries (E cm) was also measured. To estimate the volume of ascites, the area of a standard abdominal cavity in the anterior projection was assumed to be 1000 cm². The average thickness of ascites (A + B + C + D + E)/5 is then multiplied by the area to yield the volume of ascites in milliliters. The amount of ascites was calculated by the following equation:

\[(A + B + C + D + E) \times 200 \text{ (ml)}\]

The volume of ascites thus calculated was then compared with the exact volume. The exact volume of ascites considered to be the gold standard is obtained from 3D-CT with the volume rendering method using a workstation (Advantage workstation 3.1.; GE Medical Systems) (10–12).

RESULTS

The results of measurements of the exact volume of ascites by means of 3D-CT and the volume rendering method and with our conventional method are shown in Table 1. The exact volume of ascites measured by using 3D-CT ranged from 86 to 4279 ml. The average volume of ascites measured by using 3D-CT and our new method was 1493 and 1440 ml, respectively. The absolute difference in the volume measured with these two methods ranged from 1 to 467 ml. The ratio of the absolute difference in the exact volume ranged from 0.1 to 162.0% for an average of 26.2–41.7%. In two examinations where the exact volume of ascites was <300 ml, the absolute difference in the exact volume ranged from 62.8 to 162.0%. On the other hand, in 13 examinations with a volume that was not less than 300 ml as measured with the accurate volume rendering method, the ratio ranged from 0.1 to 40.8%, and the average was 12.9–13.9%. The volume measured with our conventional method consistently correlated with the volume measured with the volume rendering method (Fig. 6). The correlation was statistically significant and the correlation coefficient was 0.956 (P < 0.01).

DISCUSSION

Measurement of ascites is sometimes of considerable importance in cancer patients with peritonitis carcinomatosa, especially during the follow-up of ascites or the administration of
medication. However, no objective method to measure ascites is available at present.

The results of our study reported here demonstrated that the quantitative measurement of ascites might be achieved more easily and accurately with the aid of plain abdomino-pelvic CT images instead of with an inaccurate assessment by means of ultrasonography reported previously (13). Our method is conventional and requires neither particular expertise nor contrast enhancement. With this method, volume is calculated by using the thickness of ascites measured at five points on three CT images showing the branching off point of the superior mesenteric artery, the lower pole of the left kidney and the femoral head. This procedure is simple and reproducible. The accuracy of this method was confirmed by comparing the results with the exact values measured with the volume rendering method which is generally considered the most accurate means of measuring the volume of internal fluid without using any invasive techniques. However, because this method requires 3D scans and special expertise of a thoroughly trained radiologist, it is usually not performed to measure the volume of organs. The values for ascites calculated with our conventional method were accurate and correlated well with the accurate values obtained with the volume rendering method, especially in patients with ascites of not less than 300 ml in volume.

Since the points of measurement for this method are fixed, the question arises of whether variability in the distribution of ascites may sometimes make the measurements less accurate. However, our results show that the measurements are accurate and reproducible especially when the volume of ascites is not less than 300 ml.

In patients with ascites of small volume and in post-operative patients with bowel adherence, the distribution of ascites may be unusual, so that the points of measurement may have to be changed. As far as the patients enrolled in our study are concerned, however, no change in these points was needed.

This method adopted a rough assumption that the area of the standard abdominal cavity was 1000 cm², and used as a constant. Judging from the preliminary evaluation in the present study, the revision of the constant according to the size of the body or sex was not necessary. Other limitations of the present study included a small number of patients and a gender bias: nine out of 12 patients were female.

The accurate measurement of ascites obtained with our method should prove to be helpful for the assessment of the effect of therapeutic regimens for peritonitis carcinomatosa with ascites, and help establish criteria for therapeutic efficacy based on changes in the volume of ascites.

In conclusion, the study presented here demonstrated that the measurement of the volume of ascites with the aid of plain abdomino-pelvic CT images is practically feasible. Because this procedure is simple and easy to perform, it should be useful in many hospitals for the follow-up evaluation of ascites after treatment.

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