めに特に必要である」からである。したがって，精検機関から情報を収集した場合，その結果をがん検診の問題点の指摘と解決のために活かさなければなければならない。大阪府では，国への老人保健事業報告の締め切り（毎年６月）に約６ヵ月遅れで再度精度管理基礎調査を実施し，集計結果を大阪府生活習慣病（成人病）検診協議会での資料として提出するとともに，製本出版して市町村等に配布してきた。さらに最近では，大阪府のホームページにその概要を，各々の指標についてベストファイブとワーストファイブを示している。

なお，「今後の我が国におけるがん検診事業評価の在り方について」では，「がん検診の精度管理に用いるこれら指標については，本来であれば『対象とするがんの死亡率の減少が認められた無作為比較試験において実測された精度管理指標が再現されているか』，という観点から目標値を設定するのが妥当である」としながらも，現実的な対応として全国値の分布を用いて作成している。各がん検診を早くから先進的に行い，症例対照研究によって死亡率減少の研究を行った検診機関のデータを参照するべきではないか，と考える。例えば，胃がん検診では宮城県対がん協会のデータ，大腸がん検診では青森県総合検診センターのデータである。

がん登録との照合による感度の測定

平成19年６月にがん検診に関する検討会により示された「がん検診の事業評価の手法についてがん検診に関する中間報告」には「がんであるにもかかわらずがん検診で発見されなかった（偽陰性例）については，地域がん登録を通じて，がんの罹患に関する情報を照合した場合にのみ評価が可能であることから，がん検診の評価という観点からも地域がん登録の推進が望まれる」（p.３），とある[1]。国集計により，より正確な追跡調査データを性年齢階級別，検診方式別，検診歴別に分析することに加え，がん検診ファイルと地域がん登録ファイルとの照合により，感度・特異度を含めた精度管理評価を行うことが求められる。このために，府県では，必要な手続き・手順をクリアして，市町村からがん検診の電子ファイル（個人識別子つき）を収集し，地域がん登録と照合して偽陰性例をもれなく把握，がん検診の特異度と感度を市町村別，検診機関別に計測し公表するべきであると考える。

結語

がん検診の追跡調査結果を含めた検診事業報告は国集計から半年遅れての府集計で胃がん，大腸がん共に精検受診率やがん発見率を全国平均値以上に示すことができた。

この結果より平成20年度実績分から国集計として行われる，健康増進事業報告集計では当該年度末から約１年間の追跡期間を得るため，より実態を反映した検診成績が集約されるであろうと予測される。これらのデータを用いて，都道府県，市町村は，がん検診の精度管理・事業評価を行い，「有効な」がん検診をより「多くの人に」「正しく」実施することに努めるべきである。

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Basic considerations regarding the quality control of screening programs conducted for stomach and colorectal cancers by municipalities

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Based on the Health Enhancement Law, the responsibility for the implementation of group screening programs for cancers was given to the local municipalities in April 2008. Also, the scope of the data to be gathered and the timing of the data gathering associated with the municipality reports on the regional health status and health enhancement programs to the Ministry of Health, Labour and Welfare have changed considerably as well. In Osaka Prefecture, the Basic Prefectural Survey for the Quality Control of Screening Programs for Cancers used to be conducted approximately six months after the national survey for the Regional Health Status and Elderly People's Health Status, and this prefectural survey used to be implemented in such a manner that all the details of the thorough examinations and treatment results were included in its report. Using such survey data obtained from cancer screenings conducted for the stomach and the large intestine, we attempted to predict how the survey results would be affected by postponing the timing of the follow-up survey. We also looked at the way in which quality control must be managed in future cancer screenings. In both the group screenings and the medical examinations conducted on an individual basis, we noticed that the consultation rates for thorough examination and the cancer detection rates were both improved, and that the quality control of cancer screenings was evaluated appropriately based on detailed information, such as the results obtained from the thorough examinations and treatment findings. Concerning the results of the cancer screenings conducted in 2008 and onward, since a period longer by one year will be available for the follow-up survey, we expect that survey results will be obtained which will reflect the reality more precisely. Thus, it has been verified that a set of data suited for use as a quality control index can be obtained.

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ORIGINAL ARTICLE

Film-reading ability of radiographers in detecting gastric cancer during screening using X-ray examination

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Abstract
Purpose. The aim of this study was to evaluate the film-reading ability of radiographers in detecting gastric cancer during screening X-ray examinations.
Materials and methods. A test set of 100 patients (50 negative and 50 positive; mean age 62 years, range 33–78 years) given a stomach X-ray examination were selected from those who underwent gastric cancer screening in Osaka, Japan, between 2000 and 2003. Eleven radiographers and four radiologists scored the test set on a five-point scale. A receiver operating characteristic (ROC) analysis was performed, and the area under the ROC curve (AUC) was defined as a measure of film-reading ability to detect cancer.
Results. No significant difference (two-tailed $P = 0.962$, Welch's t-test) was observed between averaged AUC values from radiographers (0.76, range 0.85–0.62) and radiologists (0.75, range 0.86–0.62).
Conclusion. Film-reading ability of radiographers in detecting gastric cancer during screening X-ray examinations was not significantly different from that of radiologists. Our results suggest that radiographers can assist radiologists to detect gastric cancer during screening.

Key words Film reading · Radiographer · Gastric cancer screening · X-ray examination

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Introduction

An evaluation of film-reading ability of radiographers has been recently used to make better use of radiographers and to make up for the shortage in radiologists.[1-7] Methods such as the "red dot system,"[1] "reporting,"[2] and "diagnosis as a reader"[3] are used to maximize the diagnostic role of radiographers. Studies on film-reading by radiographers cover a wide area, including mammography,[4,5] plain radiography of accident and emergency patients,[6,7] chest radiography,[8] and pediatric brain computed tomography (CT).[9] These studies have demonstrated the effectiveness of film reading by radiographers. Price et al. found that radiographers at acute-care National Health Service hospitals report on multiple areas and numerous procedures, including the appendicular skeleton, axial skeleton, and chest; barium enemas; CT (head); intravenous urography (IVU) and urodynamics; mammography; nuclear medicine; pediatrics; ultrasonography; venography; and locating intraocular foreign bodies.[2]

At the same time in Japan, the shortage of physicians as film readers in gastric cancer screening using X-ray examinations has become a problem.[10,11] Furthermore, the Cancer Control Act was brought into effect in April 2007, and The Basic Plan to Promote Cancer Control Program, developed based on this law, sets a goal to "improve the consultation rate." Thus, the shortage of physicians as film readers for gastric cancer screening has become a serious problem. As the consultation rate improves, the problem is expected to become even more serious.

There are no published studies on film reading by radiographers for gastric cancer screening via X-ray examination. The aim of this study was to evaluate the film-reading ability of radiographers in detecting gastric cancer and to investigate whether radiographers can assist radiologists in detecting gastric cancer during screening X-ray examinations.

Materials and methods

Case study

The institutional review board approved the present study, and informed consent was not required because images were used retrospectively. We evaluated a test set of films from 100 patients who underwent gastric cancer screening using X-ray examinations. Films were selected from 192404 patients: 95826 men and 96578 women with a mean age of 55 years (range 19–92 years) and 274 cases of cancer. Screening was performed at a screening center in Osaka, Japan, between April 2000 and March 2003. One radiographer who did not participate as a film reader in the present study selected films from the database and randomly ordered test films for interpretation using Microsoft Office Excel 2007 software (Microsoft, Edmond, WA, USA).

The test set of 100 patients (36 men, 64 women; mean age 62 years, range 33–78 years) comprised 50 negative and 50 positive cases. Two radiologists who were certified as film readers for gastric cancer screening by the Japanese Society of Gastroenterological Cancer Screening, determined negative cases by double-blind readings. Negative cases were selected randomly from patients who underwent gastric cancer screening more than once. Negative cases were defined as selected cases that were diagnosed as negative by gastric cancer screening initially and then were still negative by gastric cancer screening within the next 1–2 years. Positive cases were selected from 274 cases of cancer that were subdivided into five categories; the category chosen depended on the difficulty of reading their films, which was determined by referring to the screening film-reading findings. Ten cases were selected from each of the five categories. Screening diagnoses were classified into five categories based on the likelihood of cancer, as determined by physicians. All cancer cases were confirmed by a comprehensive summary of findings based on clinical, surgical, and pathological findings (Table 1). Principles of recording

Table 1. Findings from 50 cancer cases[a]

Case no.	Depth of tumor invasion	Type	Tumor location	
Early cancer				
1	T1 (M)	0 I	L	Less
2	T1 (M)	0 IIa	L	Less
3	T1 (M)	0 IIa	L	Less
4	T1 (M)	0 IIb	M	Post
5	T1 (M)	0 IIc	U	Post
6	T1 (M)	0 IIc	M	Less
7	T1 (M)	0 IIc	M	Less
8	T1 (M)	0 IIc	M	Gre
9	T1 (M)	0 IIc	M	Post
10	T1 (M)	0 IIc	M	Post
11	T1 (M)	0 IIc	M	Post
12	T1 (M)	0 IIc	L	Less
13	T1 (M)	0 IIc	L	Less
14	T1 (M)	0 IIc	L	Less
15	T1 (M)	0 IIc	L	Gre
16	T1 (M)	0 IIc	L	Post
17	T1 (M)	0 IIa + IIc	L	Less
18	T1 (M)	0 IIa + IIc	L	Gre
19	T1 (M)	0 IIa + IIc	L	Gre
20	T1 (M)	0 IIc + III	M	Gre
21	T1 (M)	0 III	L	Less
22	T1 (SM)	0 IIc	U	Less
23	T1 (SM)	0 IIc	U	Less
24	T1 (SM)	0 IIc	M	Ant
25	T1 (SM)	0 IIc	M	Ant
26	T1 (SM)	0 IIc	M	Post
27	T1 (SM)	0 IIc	L	Less
28	T1 (SM)	0 IIc	L	Less
29	T1 (SM)	0 IIc	L	Ant
30	T1 (SM)	0 IIa + IIc	M	Gre
31	T1 (SM)	0 IIa + IIc	L	Less
32	T1 (SM)	0 IIa + IIc	L	Less
33	T1 (SM)	0 IIa + IIc	L	Post
34	T1 (SM)	0 IIc + III	M	Less
Advanced cancer				
35	T2 (MP)	0 IIc	M	Gre
36	T2 (MP)	1	U	Less
37	T2 (MP)	2	U	Less
38	T2 (MP)	3	UM	Less
39	T2 (MP)	3	M	Post
40	T2 (SS)	2	UM	Less
41	T2 (SS)	3	U	Less
42	T2 (SS)	3	UM	Post
43	T2 (SS)	3	M	Ant
44	T3 (SE)	0 IIc	U	Less
45	T3 (SE)	3	ML	Less
46	T3 (SE)	3	ML	Circ
47	T3 (SE)	3	L	Circ
48	T3 (SE)	4	MU	Circ
49	T3 (SE)	4	MU	Circ
50	T4 (SI)	4	MUL	Circ

Depth of tumor invasion: M, mucosa; SM, submucosa; MP, muscularis propria; SS, subserosa; SE, serosa; SI, adjacent structures
Tumor location: U, upper; M, middle; L, lower; UM, upper middle; ML, middle lower; UML, upper middle lower; Less, lesser curvature; Gre, greater curvature; Ant, anterior wall; Post, posterior wall; Circ, circumferential involvement
[a] Principles of recording follow Japanese Classification of Gastric Carcinoma[12]

Table 2. Standard radiography method for gastric cancer screening

Method
1. Examinee takes effervescent granules before the examination.
2. Examiner makes 7 exposures in the following positions and uses a roll of film 70–100 mm in width. Barium (200–300 ml, 100% w/v) is used as contrast medium.

Position
1 Double-contrast study in prone position
2 Filling method in prone position
3 Double-contrast radiograph in supine position
4 Double-contrast radiograph in supine and right anterior oblique positions
5 Double-contrast radiograph in supine and left anterior oblique positions
6 Double-contrast radiograph in semi-upright and left anterior oblique positions
7 Filling method in upright sagittal projection

followed the Japanese Classification of Gastric Carcinoma.[12]

Materials

A series of seven films was used as a standardized radiography method for gastric cancer screening (Table 2), as recommended by the 1984 Japanese Society of Gastroenterological Mass Survey.[13] Gastric cancer screening was performed using 10 screening vehicles with indirect radiographic equipment (U-MA5N; Hitachi Medical, Tokyo, Japan) and two types of indirect radiographic film (MI-FA or MI-FG; Fujifilm Medical, Tokyo, Japan) with one processing unit (CEPROS M2; Fujifilm Medical). A bloating agent (4.0 g Baros Effervescent-S; Horii Pharmaceutical, Osaka, Japan) and two barium sulfate formulations—200 ml barium sulfate, 145% w/v (Barytgen Sol 145; Fushimi Pharmaceutical, Osaka, Japan) and 200 ml barium sulfate, 150% w/v (Baritop Sol 150; Sakai Chemical Industry, Osaka, Japan)—were used.

Image interpretation

Eleven radiographers and four radiologists participated as film readers in the present study. All participating radiographers were men aged 34–57 years (median 42 years), who were certified as technologists in gastric cancer screening by the Japanese Society of Gastroenterological Cancer Screening. They did not receive film-reading training for this study. Radiographers had 12–35 years (median 18 years) of experience in gastric cancer screening using X-ray examinations. All participating radiologists were men aged 40–75 years (median 56 years), who were certified as film readers for gastric cancer screening by the Japanese Society of Gastroenterological Cancer Screening. Radiologists had 4–38 years (median 24 years) of experience in gastric cancer screening using X-ray examinations and had read films for 4000–10000 cases (median 6000) annually.

Radiographers and radiologists interpreted the test set prospectively and were blinded to information about the cases, including the history, interview sheet, and other reports. Films were scored on a five-point scale (1, negative; 2, probably benign; 3, indeterminate; 4, probably malignant; 5, malignant). A score of 2–5 was defined as positive and required diagnostic recall.

All participating radiographers and radiologists interpreted the test set in one reading room, in which the brightness was kept constant. All participating readers interpreted the test set at their own pace.

Statistical analysis

A receiver operating characteristic (ROC) analysis was performed to evaluate the overall sensitivity and specificity of each scale as a measure of film-reading ability by the radiographer or radiologist.[14–16] The area under the ROC curve (AUC) indicates the performance characteristics of a test and the index of diagnostic performance. The AUC value was defined as the film-reading ability of the radiographer or the radiologist for detecting cancer. AUC values of the radiographers and radiologists were compared, and $P < 0.05$ was considered to indicate a significant difference. The ROC analysis was performed according to methods of DeLong et al.,[17] and the comparison of averaged AUC values between radiographers and radiologists was done using Welch's t-test. We assessed the significance of our results using Statistical Software for Microsoft Excel (Analyse-it version 2.07; Analyse-it Software, Leeds, UK).

Results

Sensitivity, specificity, and AUC values of 11 radiographers and 4 radiologists are shown in Table 3. The

Table 3. Receiver operating characteristic analyses

Reader	Sensitivity	Specificity	AUC[a]
Radiographers			
A	39/50 (78%)	42/50 (84%)	0.85 (0.036) [0.77, 0.92]
B	39/50 (78%)	42/50 (84%)	0.83 (0.037) [0.76, 0.91]
C	33/50 (66%)	49/50 (98%)	0.82 (0.035) [0.75, 0.89]
D	35/50 (70%)	42/50 (84%)	0.80 (0.040) [0.72, 0.87]
E	31/50 (62%)	47/50 (94%)	0.79 (0.038) [0.71, 0.86]
F	25/50 (50%)	49/50 (98%)	0.74 (0.037) [0.67, 0.82]
G	27/50 (54%)	45/50 (90%)	0.74 (0.040) [0.66, 0.82]
H	44/50 (88%)	21/50 (42%)	0.72 (0.048) [0.62, 0.81]
I	28/50 (56%)	40/50 (80%)	0.71 (0.045) [0.63, 0.80]
J	23/50 (46%)	45/50 (90%)	0.69 (0.041) [0.61, 0.77]
K	19/50 (38%)	42/50 (84%)	0.62 (0.043) [0.54, 0.71]
Overall[b]	31/50 (64%)	42/50 (84%)	0.76 (0.040) [0.68, 0.83]
Radiologists			
A	43/50 (86%)	38/50 (76%)	0.86 (0.035) [0.79, 0.93]
B	35/50 (70%)	45/50 (90%)	0.82 (0.037) [0.75, 0.89]
C	23/50 (46%)	47/50 (94%)	0.71 (0.038) [0.64, 0.79]
D	15/50 (30%)	46/50 (92%)	0.62 (0.038) [0.54, 0.69]
Overall[b]	29/50 (58%)	44/50 (88%)	0.75 (0.037) [0.68, 0.83]

AUC, area under the curve
[a]Parentheses: standard error of area; brackets: 95% confidence interval
[b]Mean values for all readers combined

highest and lowest AUC values obtained by radiographers were 0.85 (sensitivity 78%, specificity 84%) and 0.62 (sensitivity 38%, specificity 84%), respectively. Averaged AUC value of radiographers was 0.76 (sensitivity 64%, specificity 84%). The highest and lowest AUC values obtained by radiologists were 0.86 (sensitivity 86%, specificity 76%) and 0.62 (sensitivity 30%, specificity 92%), respectively. Averaged AUC value of radiologists was 0.75 (sensitivity 58%, specificity 88%).

The averaged ROC curves for the radiographers and radiologists are shown in Fig. 1. The two curves intersected because the average sensitivity of radiographers was higher and the specificity was lower than that of radiologists. The averaged AUC value of the radiographers (AUC 0.76) was not significantly different (two-tailed $P = 0.962$, Welch's t-test) from that of the radiologists (AUC 0.75).

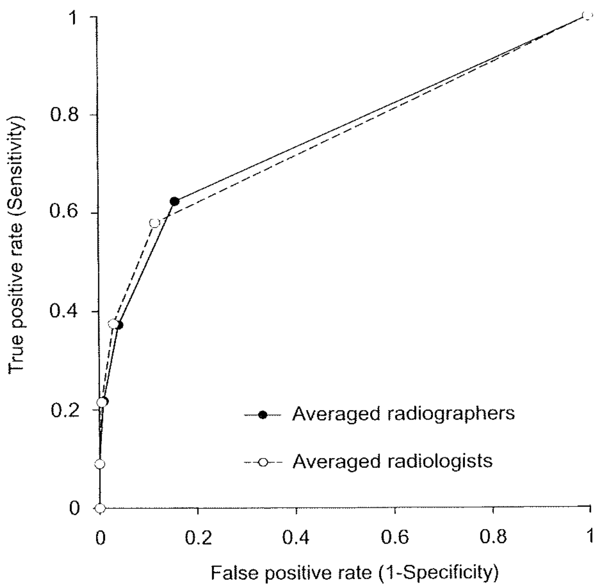

Fig. 1. Averaged receiver operating characteristic curve comparing radiographers and radiologists

Discussion

The present study evaluated the film-reading ability of radiographers to detect gastric cancer during screening X-ray examinations. Averaged AUC values revealed that the film-reading ability of the participating radiographers (AUC 0.76) did not differ significantly from that of the radiologists (AUC 0.75). This suggests that radiographers can assist radiologists in detection of gastric cancer during screening X-ray examinations.

We used an ROC analysis to evaluate the film-reading ability of radiographers and radiologists. The ROC analysis can be conducted using either discrete confidence-rating[18] or continuously distributed[19] scales. The method for continuously distributed scales does not require observers to select the category, and observers simply characterize the presence of an abnormality in image samples only. Thus, in comparison to the method for discrete confidence-rating scales,[19] this method is simple to learn and requires no special experience. In the present study, however, the ROC analysis was performed using a five-category discrete scale. This is because routine screening diagnoses for gastric cancer using X-ray examinations are often performed according to five categories as recommended by the 1983 Japanese Society of Gastroenterological Mass Survey, which depend on the likelihood of cancer as determined by a physician.[20] Some institutions classify screening diagnoses into modified five or six categories.[21] As participating radiologists in the present study routinely arrive at a diagnosis using five categories dependent on their own assessment of the level of cancer, we decided that it would be best to use methods to which they are accustomed.

The test set proportion of negative cases to positive cases for the present study was 50:50. This proportion is relatively large in comparison to what is observed in gastric cancer screening, as the gastric cancer detection rate in Japan is 0.10% (negative to positive is 1000:1).[22] However, as Gur et al. found, variability in prevalence did not affect observer performance using ROC analysis.[23] The proportion of negative to positive cases used in the present study should be appropriate for evaluating film-reading ability.

Using ROC analysis, Brealey et al. also found no significant differences in reporting between radiographers and radiologists in a variety of clinical settings, and they concluded that radiographers have the potential to expand their reporting role.[7] Brealey et al.'s findings support the conclusions of the present study. However, whereas Brealey et al. evaluated the film-reading ability of radiographers trained in interpretation, the present study did not train participating radiographers. Sumkin et al. evaluated the film-reading ability of untrained radiographers in breast cancer screening and showed that radiographers and radiologists agreed in 82% of the cases (77% negative findings and 5% requiring follow-up).[24] They concluded that even without additional training radiographers can, with reasonable accuracy, classify screening mammograms. The use of radiographers as film readers for diagnostic purposes should be accompanied by specialized training.

Currently, radiographers read mammograms to detect cancer in the National Health Service Breast Screening Programme (NHSBSP).[25,26] Radiographers are required to receive professional education and qualification for film reading in the NHSBSP. In the future, Japanese radiographers will be required to have more than just film-reading ability equivalent to that of radiologists if they are to participate in making a diagnosis during gastric cancer screening. They will likely need a broader, more advanced professional education that includes medical knowledge and ethics. Such an education will better equip them to become valuable assets to the medical community.

The present study has several limitations. Participating radiographers had at least 12 years of radiographic technique experience. As such, we expected that they have attained a certain level of mastery of radiographic technique, but their proficiency in film reading was unknown. Their overall film-reading ability may be higher than that of novices owing to their 12+ years of experience, which includes participation in monthly institutional clinical conferences and self-motivated participation in study meetings. In addition, the present study used a method to compare the averaged AUC of 11 radiographers and 4 radiologists. As such, the results may not be applied to assess the film-reading ability of a broad range of radiographers and radiologists. Future studies should clarify differences in film-reading ability of radiographers and radiologists from multiple institutions.

Conclusions

Radiographers did not differ significantly from radiologists in their film-reading ability to detect gastric cancer during screening X-ray examinations. We suggest that radiographers can assist radiologists in detecting gastric cancer during screening.

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SCIENTIFIC NOTE

Radiation dose in mass screening for gastric cancer with high-concentration barium sulfate compared with moderate-concentration barium sulfate

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Abstract

Recently, high-concentration barium sulfate has been developed and is used in many medical facilities. This study compared radiation dose using high-concentration and moderate-concentration barium sulfate. The dose was evaluated with an experimental method using a gastric phantom and with a clinical examination. In the former, the dose and X-ray tube load were measured on the phantom with two concentrations of barium sulfate. In the latter, the fluoroscopic dose–area product (DAP), the radiographic DAP and their sum, the total DAP, were investigated in 150 subjects (112 males, 38 females) treated with both concentrations of barium sulfate. The effective dose was calculated by the software of PCXMC in every case. The results of the experimental evaluation indicated that the effective dose and X-ray tube load were greater with high-concentration barium sulfate than with moderate-concentration barium sulfate ($p < 0.05$). The results of the clinical evaluation indicated that the fluoroscopic DAP was greater with moderate-concentration barium sulfate than with high-concentration barium sulfate ($p < 0.05$), but the radiographic DAP was quite the reverse, so the total DAP and effective dose were almost same with both concentrations of barium sulfate. We conclude that high-concentration barium sulfate does not increase radiation dose in mass screening for gastric cancer.

Key words radiation dose, high-concentration barium sulfate, gastric cancer mass screening

Introduction

The mortality rate from gastric cancer in Japan is considerably higher than that in the rest of the world[1], but it is declining. Mass screening for gastric cancer with X-rays is now in general use in Japan and is considered to be effective[2,3]. Screening is considered one of the factors associated with the reduction in the mortality rate from gastric cancer. Guidelines for gastric cancer screening in Japan have recently been proposed[4]. In this type of screening, barium sulfate is used as the contrast medium. Recently, high-concentration barium sulfate has been developed and is used in many medical facilities. The Osaka Cancer Prevention and Detection Center has used high-concentration barium sulfate since 2000, and has confirmed that the mucosal adhesion of high-concentration barium sulfate is better than that of moderate-concentration barium sulfate[5]. However, the evidence from a systematic review of previous studies of gastric cancer screening using high-concentration barium sulfate was unclear. The early cancer detection rates with screening using high-concentration barium sulfate do not differ from those with moderate-concentration barium sulfate[6]. Further appropriate research is obviously required to clarify the efficacy of the new method[6].

There is concern that the radiation dose increases during X-ray-based examinations when high-concentration barium sulfate is used. Japan has the highest attributable risk, with 3.2% of the cumulative risk of cancer (cancer incidence) attributable to diagnostic X-rays, equivalent to 7,587 cases of cancer per year[7]. It is important to avoid any further increase in the radiation dose associated with X-ray examinations.

In this study, we investigated whether the use of high-concentration barium sulfate resulted in an increased dose of radiation. The dose was evaluated with an experimental method using a simple gastric phantom and with a clinical examination of 150 subjects, to compare high-concentration and moderate-concentration barium sulfate.

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Materials and methods

Barium sulfate

Barytgen Sol 145 w/v% sol (Fushimi Pharmaceutical Co., Ltd., Marukame, Japan) was used as the moderate-concentration barium sulfate, abbreviated to 145A barium. Baribright P 185 w/v% powder (Kaigen Co., Ltd., Osaka, Japan) was used as the high-concentration barium sulfate, abbreviated to 185B barium.

Gastric phantom

A simple phantom was made of acrylic board (5.0 mm × 300.0 mm × 300.0 mm), at the center of which was a circular recess (2.0 mm × 200.0 mm) and a ready-made Mix-Dp phantom (300.0 mm × 300.0 mm; Sanwa Chemical Co., Ltd., Osaka, Japan). The acrylic board was 5.0 mm thick. The depth of the recess on acrylic board was 2.0 mm. An air cavity of 10.0 mm was also made in the recess. The size of air cavity on the phantom (11.0 mm) was determined on the assumption that the air cavity of the gastric body in the supine frontal position is 11 mm. The arrangement of the acrylic board and the Mix-Dp phantom is shown in Fig. 1.

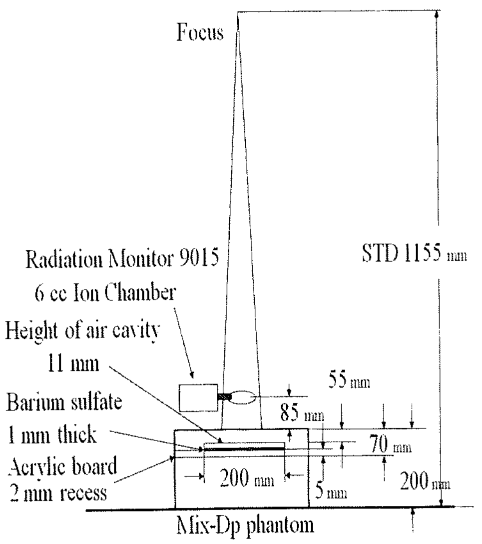

Figure 1. *Schematic drawing of the phantom arrangement in the experimental evaluation.*

Measurements of dose and X-ray tube load with the phantom

The dose of radiation and X-ray tube load were measured with 30 mL of each type of barium sulfate adhering (1 mm thick) to the recess in the acrylic board. A radiography/imaging plate combination-type cassetteless fluorography device (ZS–40 TV Fluoroscopy Device, Shimadzu Co., Ltd., Kyoto, Japan) was used. The distance between the X-ray tube focus and the image intensifier was 1200 mm. A radiation monitor (9015, Radcal Corporation, Monrovia, Liberia) and a 6 cc ion chamber (10X5–6M, Radcal Corporation) were used as the dosimeter. The ion chamber was placed 85 mm above the phantom surface to avoid backscatter from the phantom. The X-ray tube voltage was varied from 80 kV to 110 kV with reference to AEC clinical examinations, in which the voltage was changed over the range of 80 – 110 kV according to patient's position and physique. The exposure was 320 mA, regulated with an automatic exposure control (AEC). The dose (mGy) and the X-ray tube load (mAs) were measured six times at 26 °C for each concentration of barium sulfate. The barometric pressure was 100.5 kPa and the exposure field was 100 × 100 mm^2 on the top of the simple phantom. This exposure size was the minimum size to allow the highest dose for the measurement in air. The effective dose was calculated by the software of PCXMC dose calculations Ver. 1.5.1. (STUK – Radiation and Nuclear Safety Authority, Helsinki, Finland). Every value was expressed as the mean ± standard deviation (SD).

Clinical subjects and DAP measurements

The subjects included 150 patients (112 males, 38 females) selected from 21,140 medical examinees who attended the Osaka Cancer Prevention and Detection Center over a four-year period from April 1998 to March 2002. The protocol for this study was approved by the Ethical Committee of our institution (The Osaka Cancer Prevention and Detection Center). In clinical practice in Japan, screening for gastric cancer is performed once a year. In gastric cancer screening, moderate-concentration barium sulfate was used until 1999, whereas high-concentration barium sulfate has been used since 2000. The study subjects consisted of examinees who had been screened with moderate-concentration barium sulfate in 1999 and with high-concentration barium sulfate in the following year. Identical numbers of radiographs were taken by the same radiological technologist using the same X-ray tube, image intensifier and TV fluoroscopy device in the two screenings. The fluoroscopic dose and the radiographic dose were investigated as the dose–area product (DAP, Gycm^2) in all 150 subjects and the sum of both constituted the total DAP. Every DAP was converted to effective dose by the software of PCXMC dose calculations. The chamber of the area dosimeter (Diamentor-M PTW-Freiburg Co., Ltd., Freiburg, Germany) was placed in front of the collimator. The values were expressed as means ± SD.

Statistical analysis

Statistical differences in the measured dose, and effective dose and X-ray tube load using the phantom were analyzed with an unpaired t test. Statistical differences in DAP and effective dose for the clinical subjects were analyzed with a paired t test. Differences were considered significant when $p < 0.05$. Statistical analyses were performed using SPSS 11.5J for Windows (SPSS Japan Inc., Tokyo, Japan).

Results

Dose and X-ray tube load with the phantom

Comparisons of the measured dose (a) and the effective dose (b) with both concentrations of barium sulfate are shown in Fig. 2. The measured dose and effective dose with

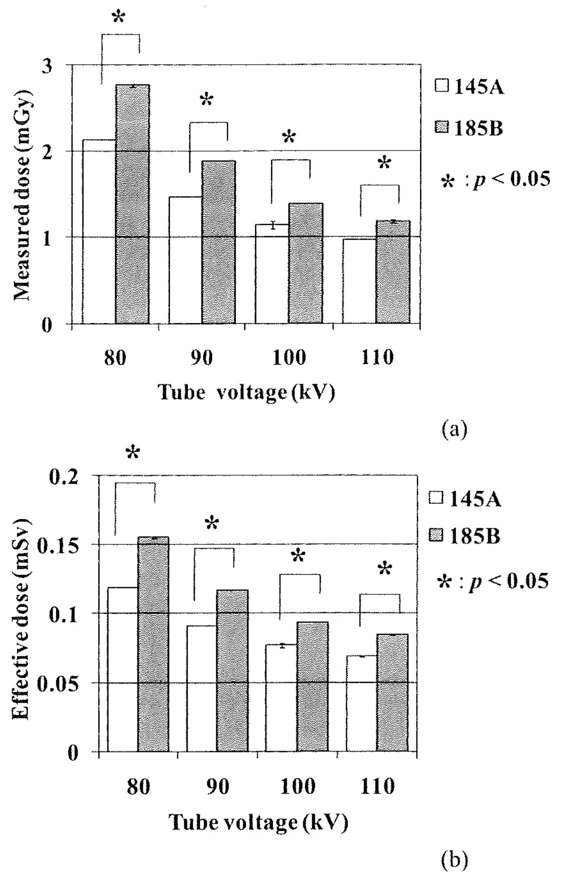

Figure 2. *Measured dose (a) and effective dose (b) in the experimental evaluation. 145A:145A barium, 185B:185B barium.*

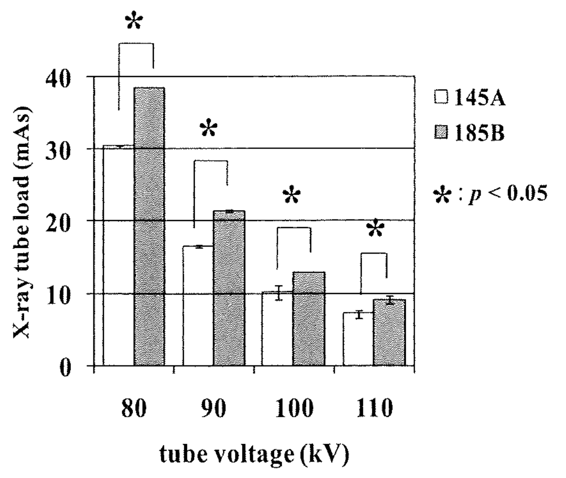

Figure 3. *X-ray tube load in the experimental evaluation. 145A:145A barium, 185B:185B barium.*

185B barium are greater than those with 145A barium at every voltage (80–110 kV). A comparison of the X-ray tube loads for both concentrations of barium sulfate is shown in Fig. 3. The X-ray tube load for 185B barium exceeds that for 145A barium at every voltage (80–110 kV). These results indicate that the effective dose and X-ray tube load are greater with high-concentration barium sulfate than with moderate-concentration barium sulfate ($p < 0.05$).

Dose–area product (DAP) in clinical subjects

Comparisons of the fluoroscopic and radiographic DAP (a), and effective dose (b) experienced on the clinical subjects are shown in Fig. 4. The fluoroscopic DAP and effective dose are greater in subjects treated with 145A barium than in subjects treated with 185B barium ($p < 0.05$), but the radiographic DAP and effective dose are quite the reverse ($p < 0.05$). Consequently, the total DAP and effective dose are almost same for two concentrations of barium sulfate.

Discussion

The efficacy of high-concentration barium sulfate has been reported from several perspectives[5], as discussed above. Compared with moderate-concentration barium sulfate, a high concentration improves the image quality of the gastric fornix[8]. Furthermore, high-concentration barium sulfate is easy to drink because of its low viscosity and small intake volume[9]. However, there has been little study of its effect on the radiation dose. There is little radiation

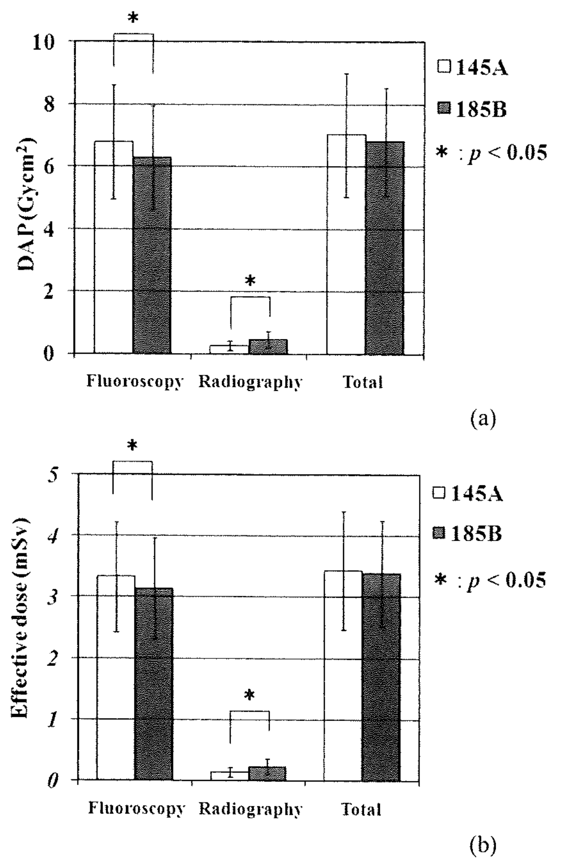

Figure 4. *Fluoroscopic and radiographic DAP (a) and effective dose (b) in the clinical evaluation. DAP: dose-area product, 145A:145A barium, 185B:185B barium.*

hazard involved in mass screening for gastric cancer[10], but the medical radiation dose in Japan is the highest in developed nations[7]. Therefore, it is necessary to minimize the dose of radiation on the basic premise of "as low as reasonably achievable"[11].

In this study, we examined the difference in radiation dose received when 185B high-concentration barium sulphate and 145A moderate-concentration barium sulphate were used in mass screening for gastric cancer. Our experimental evaluation with a simple phantom showed that the effective dose and X-ray tube load were greater with 185B barium than with 145A barium. This result is consistent with the greater absorption of X-radiation by high-concentration barium sulfate, which may cause anxiety among medical examinees when high-concentration barium sulfate is used.

In our clinical evaluation, the fluoroscopic DAP and effective dose with 145A barium were greater than those with 185B barium ($p < 0.05$), but the radiographic DAP and effective dose were less with 145A than those with 185B ($p < 0.05$). Consequently, the total DAP and effective dose, the sum of the fluoroscopic and radiographic DAP and effective dose were almost same with the two concentrations of barium sulfate. The lower fluoroscopic DAP achieved with high-concentration barium sulfate resulted from the shorter time necessary for the fluoroscopic exposure. The quality of the fluoroscopic images obtained with high-concentration barium sulfate was satisfactory. These results suggest that high-concentration barium sulfate does not increase radiation dose in screening for gastric cancer.

Conclusion

Our experimental evaluation indicated that effective dose was greater with high-concentration barium sulfate than with moderate-concentration barium sulfate, but the clinical evaluation showed almost same effective dose between both barium sulfates. The authors conclude that high-concentration barium sulfate does not increase radiation dose in screening for gastric cancer.

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Viscosity Change of High Concentration Barium Sulfate Dependent on the Volume of Artificial Gastric Juice

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High concentration barium sulfate has been developed and used in mass screening for gastric cancer. However, high concentration barium sulfate flows out from the stomach faster than moderate concentration one, which often interferes with diagnosis. The speed of flow is seemed to depend on the viscosity of barium sulfate. Previously, the authors reported viscosity changes of high concentration barium sulfate with pH and temperature changes. In this study, it is examined that the viscosity of barium sulfate also changes with artificial gastric juice volume. The results indicate that the viscosity of high concentration barium sulfate is more stable than that of moderate concentration one and the image of gastric phantom with high concentration barium sulfate is evaluated to be better than that with moderate concentration one. The study on characteristics of barium sulfate may improve radiography technology in mass screening for gastric cancer.

Key Words: high concentration barium sulfate, viscosity, volume of artificial gastric juice, mass screening for gastric cancer

I Introduction

As contrast media used in mass screening for gastric cancer, high concentration barium sulfate has been developed and indicated to be effective in many reports [1 - 4]. Osaka Cancer Prevention and Detection Center has started to adopt high concentration barium sulfate since 2004 and confirmed that it is superior in adhesion to gastric mucosa and satisfactory for mucosal visualization ability [5]. Although high concentration barium sulfate is hypo in viscosity and good on gastric fluidity, it flows out fast from the stomach, which might result in inaccurate diagnosis. The flow speed is usually influenced by gastric form, physical position on radiography and the viscosity of barium sulfate. The authors already reported viscosity changes with pH of artificial gastric juice and temperature on recently used high concentration barium sulfate and past used moderate concentration one [6]. X-ray radiographs of gastric phantoms applied by these barium sulfates were also evaluated in quality [6]. Other reports [7, 8] indicated the viscosity change of barium sulfate with temperature and pH. However, there is little study on the relation between the viscosity of barium sulfate and the volume of gastric juice.

The aim of this study is to examine the viscosity change of barium sulfate with the volume change of gastric juice. Practically, viscosity changes of three types of barium sulfate, two types of high concentration ones and one type of moderate concentration one, are studied with volume changes of artificial gastric juice, and x-ray radiographs of gastric phantoms applied by three types of barium sulfate are visually evaluated.

II Materials and Methods

1. Contrast media

Barytgen Sol 145w/v% sol (FUSHIMI Pharmaceutical, Marukame, Japan) was used as a moderate concentration barium sulfate and abbreviated to 145A barium. Baribright P 185w/v% powder (Kaigen, Osaka, Japan) and Barytgen HD 200w/v% powder (FUSHIMI Pharmaceutical, Marukame, Japan) were used as high concentration barium sulfate and abbreviated to 185B barium and 200C barium, respectively.

2. Artificial gastric juice and viscosity measurements

Artificial gastric juice was made of HCl and distilled water. Certain volume (20 ml, 30 ml, 40 ml, 50 ml and 60 ml) of artificial gastric juice was mixed with 150 ml of each barium sulfate. Every mixture was 25.0℃ and pH 1.2. The viscosity was measured at 30 rpm by type B viscometer (BH type, TOKIMEC, Osaka, Japan) with NO.1 rotor in the cases of 185B barium and 200C barium and with NO.2 rotor in the case of 145A barium.

3. Radiographs of gastric phantom

Gastric phantom BMU-1 (Kyoto Chemistry Specimen, Kyoto, Japan) was used and three types of barium sulfate containing artificial gastric juice of 20 ml, 30 ml, 40 ml, 50 ml, 60 ml and 70 ml were applied to the phantom. Radiographs of these phantoms were taken using x-ray film / IP combination type cassette-less fluorography device ZS-40 (abbreviated to TV fluorography device, Shimadzu, Kyoto, Japan). The radiographs (PFH-T FILM Eastman Kodak, Rochester, USA) of gastric phantom were visually evaluated by seven examiners of five radiological technologists and two doctors.

4 . Statistical analyses

The results were compared among groups by one-way analysis of variance (ANOVA). If significant, they were examined by Bonferroni-Dunn multiple comparisons post-hoc test, with the level of statistical significance taken as $p < 0.05$. Pearson's correlation was used. Statistical analyses were performed using SPSS 15.0 J (SPSS Japan, Tokyo, Japan) for Windows.

Ⅲ Results

1 . Viscosity

Viscosity changes of 145A barium, 185B barium and 200C barium by respective volume of artificial gastric juice are shown in Fig. 1. The figure shows that on two types of high concentration barium sulfate, 185B barium and 200C barium, viscosity slightly decreases with the volume increase of artificial gastric juice. However, the viscosity of moderate concentration one, 145A barium, tends to increase with the volume increase of artificial gastric juice until 50 ml and to decrease beyond that. The viscosity of 145A barium is generally high, especially on 40 ml and 50 ml of artificial gastric juice, compared with those of 185B barium and 200C barium which inversely correlate with the volume of artificial gastric juice (185B barium : $r = -0.967$, 200C barium : $r = -0.950$).

The viscosity changes of 185B barium and 200C barium are smaller than that of 145A barium ($p < 0.05$), and the viscosity of 200C barium is rather stable than that of 185B barium.

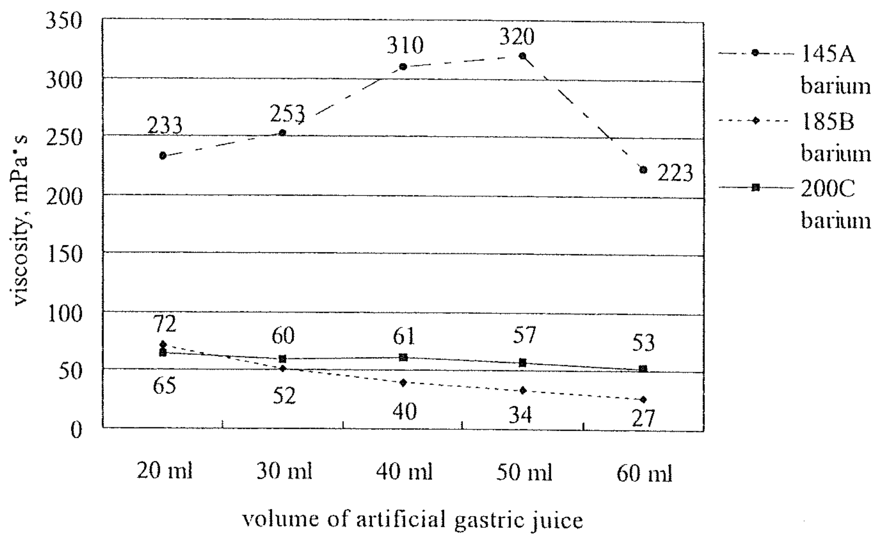

Fig. 1 Viscosity change of barium sulfate dependent on the volume of artificial gastric juice

2 . Radiographs

Radiographs of gastric phantom are shown in Fig.2 on 145A barium, in Fig.3 on 185B barium and in Fig. 4 on 200C barium. The visual evaluation of these radiographs by seven examiners is that the mucosa adhesion of 200C barium is better than those of 145A barium and 185B barium.

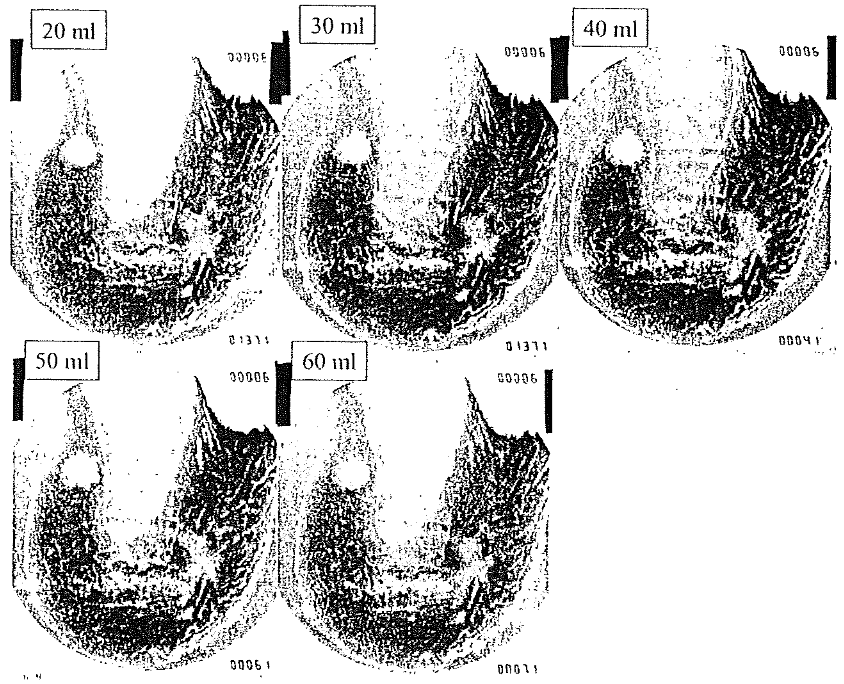

Fig. 2 Radiographs of gastric phantom (145A barium)

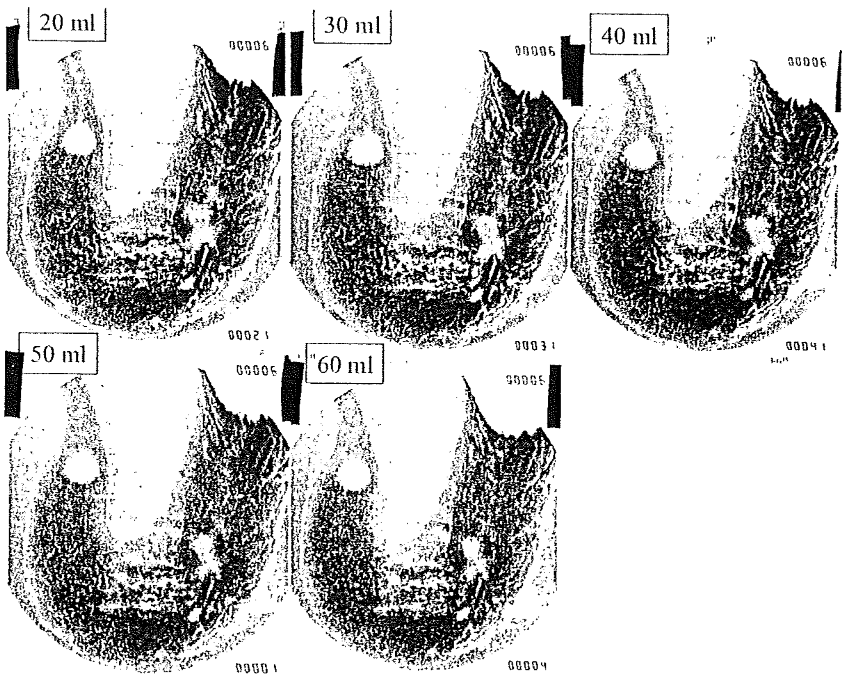

Fig. 3 Radiographs of gastric phantom (185B barium)

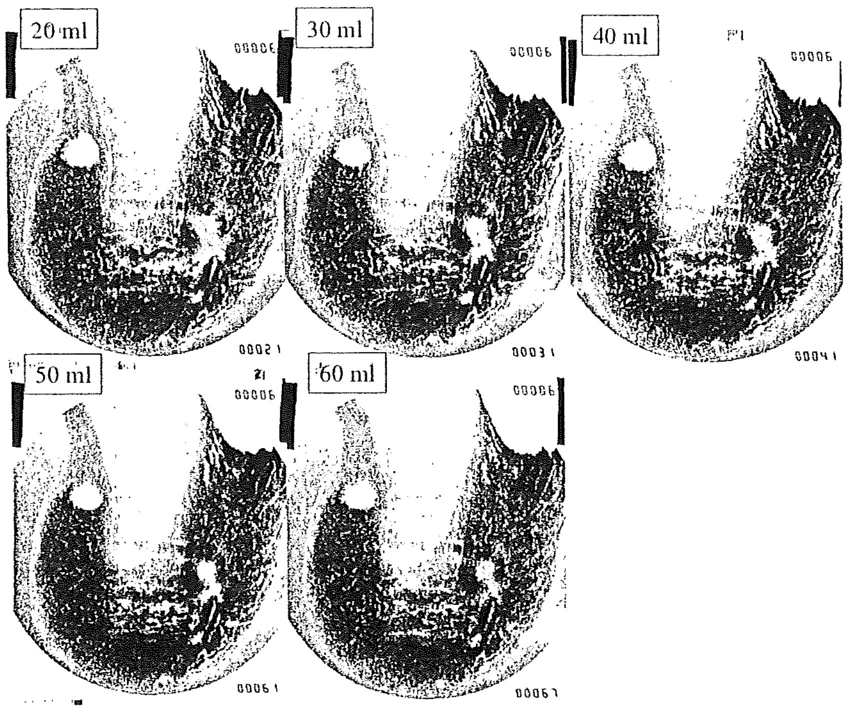

Fig. 4 Radiographs of gastric phantom (200C barium)

Ⅳ Discussion

When the viscosity of barium sulfate is too low, barium sulfate flows out fast from the stomach before satisfactory radiography. When the viscosity is too high, barium sulfate stagnates and condenses in the stomach [5]. The authors examined viscosity changes of barium sulfate with pH and temperature changes on two types of high concentration one, 185B barium and 200C barium, and one type of moderate concentration one, 145A barium and reported that the viscosity decreased with pH and temperature increases and inversely correlated with pH for three types of barium sulfate [6]. For gastric radiography, 185B barium was the best among three types of barium sulfate [6].

In this study, viscosity changes of three types of barium sulfate were examined on the correlation with volume of artificial gastric juice and radiographs of phantom applied by three types of barium sulfate were visually evaluated. The results showed that viscosity slightly decreased with volume increase of artificial gastric juice on two types of high concentration barium sulfate, 185B barium and 200C barium, but the viscosity of 145A barium at first increased and then decreased with volume increase of artificial gastric juice. Compared to 145A barium, 185B barium and 200C barium were stable in viscosity for volume changes of artificial gastric juice ($p < 0.05$). The viscosity of 200C barium was rather stable between the two. The visual evaluation of phantom radiographs indicated that the mucosa adhesion of 200C barium was better than those of 145A barium and 185B barium.

The previous report [6] showed that the mucosa adhesion of 185B barium was the best among three types of barium sulfate with pH and temperature changes. Anyway, high concentration barium sulfate is a useful contrast medium for gastric cancer mass screening and a good command is seemed to choice either 185B barium or 200C barium according to the gastric condition of medical examinee.

V Conclusion

The viscosity of high concentration barium sulfate, 185B barium or 200C barium, is more stable than that of a moderate concentration one, 145A barium, on volume change of artificial gastric juice. Between 185B barium and 200C barium, the latter is stable on viscosity and good on mucosa adhesion shown in radiographs.

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胃がん検診で用いる高濃度硫酸バリウム製剤の人工胃液量変化に伴う粘度変化

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高濃度硫酸バリウム製剤は胃がん検診のために開発され，広く利用されている。しかし，胃外への流出が早く，診断の妨げになることがある。この流出速度は，硫酸バリウム製剤の粘度に依存すると考えられる。著者らは，以前，人工胃液のpHや温度変化に対する高濃度硫酸バリウム製剤の粘度変化を報告した。本研究では，人工胃液量の変化に伴う硫酸バリウム製剤の粘度変化を調べ，高濃度硫酸バリウム製剤の粘度が安定し，その製剤を用いた胃ファントム画像も良好であることを確認した。
このような硫酸バリウム製剤の検討は，胃がん検診技術の向上に寄与すると考えられる。

キーワード：高濃度硫酸バリウム製剤，粘度，人工胃液量，胃がん検診