Do additional x-rays taken by a radiographer during x-ray screening for gastric cancer improve detection?

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Abstract— **The purpose of this study was to investigate the potential benefits of additional x-rays in detecting gastric cancer during x-ray screening. We analyzed 151 gastric cancer cases among 136,450 individuals who underwent x-ray screening for gastric cancer. X-rays were performed by 10 radiographers at a single screening center in Japan from 2000 to 2002. Additional x-rays were taken based on the radiographer's judgment in cases of suspected cancer lesions. During reinterpretation of the x-rays of cancer cases by 2 radiologists, we determined the number of cancer cases that were detected by standard x-rays alone. We next determined the number of cancer cases detected using both standard x-rays and additional x-rays. We then investigated whether additional x-rays increased the rate of cancer detection. The number of cancer cases detected by standard x-rays alone was 122 and the number of cancer cases detected by standard x-rays and additional x-rays was 151. We observed a significant increase in cancer detection with the use of additional x-rays when judged necessary by the radiographer (29 cases, $P = 0.007$, Wilcoxon signed–ranks test). No statistically significant correlation was observed between the number of additional x-rays performed and the increased rate of cancer detection due to additional x-rays taken arbitrarily ($rs = -0.38$, $P = 0.28$, Spearman's rank correlation). We found ,that additional x-rays, performed when judged to be necessary by the radiographer during screening, can identify cases of cancer which are not detectable with the standard x-rays alone.**

Keywords— **radiographer, additional photography, x-ray examination, gastric cancer screening**

I. Introduction

Gastric cancer is common in Japan, Central Europe, Scandinavia, Hong Kong, South and Central America, China, Korea [1]. Particularly in Japan, gastric cancer screening using x-ray radiography is used for early detection and treatment. Although the value of gastric cancer screening is well recognized [2], the 10–40% rate of false negatives [2] demonstrates the need for increased screening accuracy.

Gastric cancer screening using x-ray radiography is performed following standard radiographic methods [3-5]. However, cancer lesions cannot always be identified from standard x-rays, even when abnormal findings suggest the presence of cancer [6]. The radiographer is able to observe the stomach through the fluoroscope during screening and in the event of an abnormal finding during this observation, the radiographer may decide to perform additional x-rays. Additional x-rays may be taken while the patient is in a body position that enables better observation of the area in question or under conditions that increase barium flow over the cancer. Although the usefulness of taking additional x-rays has previously been reported [7, 8], it has not been determined whether additional x-rays improve the diagnosis of gastric cancer. The high false negative rate during screening may be due to insufficient use of additional x-rays, or differences in radiographers' techniques [9].

In this study, we investigated whether taking x-rays in addition to standard x-rays, based on the radiographer's judgment during screening, increases the detection of gastric cancer, thus clarifying the diagnostic value of additional x-rays during gastric cancer screening.

II. Materials and Methods

A. Case study

The Institutional Review Board approved the present study and informed consent was not required because images were used retrospectively.

The screening was performed at a screening center in Osaka, Japan between April 2000 and March 2002. A total of 136,450 individuals underwent x-ray screening (65,612 males and 70,838 females; mean age 55 years; range 19–92 years; 221 cases of cancer). X-rays were performed by 10 radiographers using 10 gastric cancer screening cars and 2 fluoroscopic devices on site.

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Table 1 shows the number of patients assessed by each radiographer. Of these, we analyzed 151 cases (98 cases of early stage gastric cancer) for which films could be viewed.

B. Materials

Gastric cancer screening was performed using 10 screening cars and 2 fluoroscopic devices on site with indirect radiographic equipment (U-MA5N; Hitachi Medical, Tokyo, Japan). Two types of indirect radiographic film (MI-FA or MI-FG; Fujifilm Medical, Tokyo, Japan) and two kinds of barium sulfate formulation (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.

C. Radiographic and interpretation methods

A series of 7 films was used as a standardized method for gastric cancer screening (Table 2), as recommended by the 1984 Japanese Society of Gastroenterological Mass Survey [4].

For cases in which cancer was suspected during screening, additional x-rays were taken based on the radiographer's judgment. Because the optimal number of additional x-rays is not specified in the radiographic method proposed by the Japanese Society of Gastroenterological Mass Survey, we set the maximum number at 5 to prevent the additional number of x-rays per case from becoming too large.

Ten radiographers took the x-rays. All participating radiographers were male, aged 30–52 years (median 36), and were certified as technologists in gastric cancer screening by the Japanese Society of Gastroenterological Cancer Screening. The radiographers had 8–25 years (median 13) of experience in gastric cancer screening using x-ray examination. X-ray interpretation was performed by 19 physicians certified by the Japanese Society of Gastroenterological Cancer Screening conducting dual reading of x-rays.

Table 1 Subjects

Radiographer	Subjects	(male, female)
1	14139	(6721, 7418)
2	16257	(7796, 8461)
3	12893	(5562, 7331)
4	13085	(6511, 6574)
5	12407	(6568, 5839)
6	10392	(5505, 4887)
7	13071	(7670, 5401)
8	14434	(6092, 8342)
9	13837	(5957, 7889)
10	15935	(7230, 8705)
total	136450	(65612, 70838)

D. Investigation of the number of cancer cases which became extractable by additional x-rays

Two radiologists (years of experience, 30 and 27; age, 57 and 55 years) certified by the Japanese Society of Gastroenterological Cancer Screening performed a blinded re-interpretation of x-rays for cancer cases.

Re-interpretation was first conducted using standard x-rays alone, and the number of cancer cases detected was determined separately for each radiographer. Next, re-interpretation was performed with both standard x-rays and additional x-rays, and the number of detected cancer cases was determined separately for each radiographer. The two numbers of cancer detection were compared and the difference was tested with the Wilcoxon signed rank test.

E. Investigation of differences between radiographers in cancer detection by additional x-rays

We defined the rate of cancer detection increase due to additional x-rays as the ratio of the number of cancer cases detected with both standard x-rays and additional x-rays to the number of cancer cases detected with standard x-rays alone. Using Fisher's exact test, we determined whether a difference existed between radiographers in the rate of cancer detection increase due to additional x-rays. We further investigated whether the rate of cancer detection increase due to additional x-rays was increased by arbitrarily taking

Table 2 Standard method of radiography in the gastric cancer screening

	Method
Examinee is asked to take effervescent granules before examination	
Examiner is to make 7 exposures in the following positions, and to use a roll of film 70-100 mm in width, and 200-300 ml barium, 100 w/v%, 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 position
5	Double-contrast radiograph in supine and left anterior oblique positions
6	Double-contrast radiograph in semiupright and left anterior oblique positions
7	Filling method in upright sagittal projection

additional x-rays even when abnormalities were not observed by the radiographer. To investigate this possibility, we randomly sampled x-rays from 100 subjects of each radiographer of the 136,229 normal cases and determined the mean number of additional x-rays taken. Next, we produced a scatter plot and calculated Spearman's rank correlation to determine the relationship between the mean number of additional x-rays taken for normal cases and the rate of cancer detection increase associated with these additional x-rays for each radiographer.

F. Statistical tests

To test for significance, we used the 'Analyse-it' Statistical Software for Microsoft Excel (version 2.05; Analyse-it Software, Leeds, United Kingdom). A p-value less than 0.05 was considered significant.

III. Result

A. Investigation of the number of cancer cases identified with additional x-rays

Compared to the 10 radiographers' number of cancer cases detected with standard x-rays alone (total, 122; median, 11; range, 8–23), the number of cancer cases detected with both standard and additional x-rays (total: 151, median: 15, range 9–29) significantly increased (P = 0.007, Wilcoxon signed rank test) (Fig. 1).

B. Investigation of differences between radiographers' ability to identify cancer using additional x-rays

The median rate of cancer detection increase due to additional x-rays for all radiographers was 1.2 (range 1.0–2.0) (Fig. 1). A significant difference in rates of detection using additional x-rays was observed between radiographers with the highest (2.0) and lowest (1.0) rates of detection (P = 0.038, Fisher's exact test).

No statistically significant correlation was observed between the mean number of additional x-rays for normal cases (median, 1.9; range, 1.6–2.8) and the rate of cancer detection increase due to additional x-rays. (Fig. 2) (rs = -0.38, P = 0.28, Spearman's rank correlation).

IV. Discussion

We found that the number of cancer cases not detected by standard x-rays alone was extremely high. We also observed a significant increase in gastric cancer detection when comparing the number of cancer cases detected with both standard and additional x-rays to the number of cancer cases detected with standard x-rays alone. These results

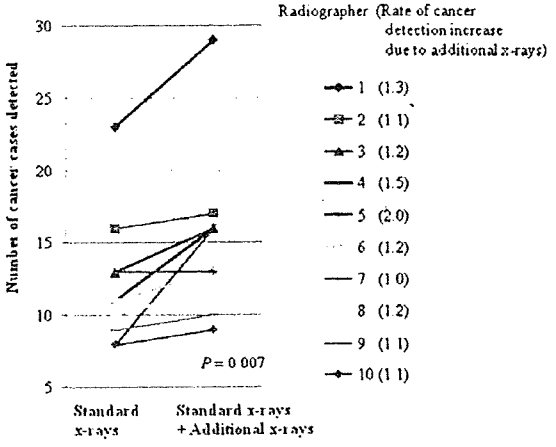

Fig. 1 The number of cancer cases detected by standard radiography alone, the number of cancer cases detected by standard x-rays and additional x-rays, and the rate of cancer detection increase due to additional x-rays, by radiographer

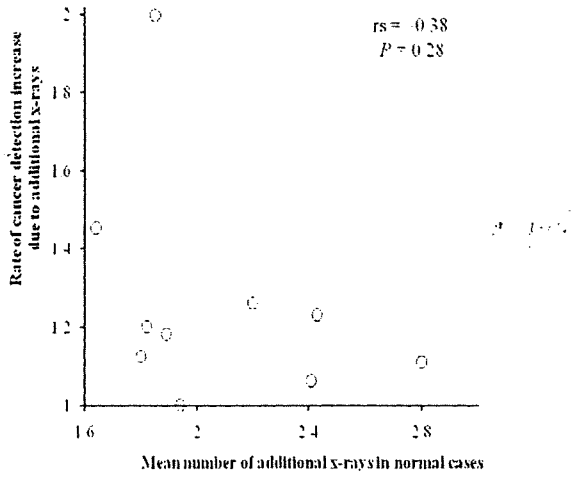

Fig. 2 Relationship between mean number of additional x-rays in normal cases and the rate of cancer detection increase due to additional x-rays for each radiographer

demonstrated that when cancer lesions cannot be identified with standard x-rays, they may be detected by performing additional x-rays when judged necessary by the radiographers based on abnormal findings in an observation.

As a result of examining the rate of cancer detection increase due to additional x-rays separately for each radiographer, large differences were observed in the conditions that enabled cancer detection among the radiographers. This raises the possibility that detection of cancer may depend on the radiographer performing the x-rays and underscores the importance of improving radiographers' techniques.

We did not observe a correlation between the mean number of additional x-rays for normal cases for each radiographer and the rate of increased cancer detection. This suggests that the greater number of cancer cases being detected was not due to unnecessary additional x-rays. It is important to take additional x-rays only for cases in which an abnormal finding suggests cancer.

There is a limitation worth noting in this study. While we set the upper limit for the number of additional x-rays at 5, we have not determined the validity of this number. The maximum number of 5 was determined by considering that approximately 2 additional x-rays would be required in cases in which a blind area existed, and approximately 3 additional x-rays would be needed in cases of abnormal findings. However, the upper limit for the number of additional x-rays should be determined by also considering the risks associated with radiation exposure that accompanies an increase in the number of x-rays.

V. Conclusions

In this study, we found that additional x-rays in gastric cancer screening, when determined to be necessary by the radiographer, significantly increases the number of detected cancer cases which cannot be diagnosed with standard x-rays alone. We also found that the ability to extract cancer lesions with additional x-rays varied significantly among radiographers. These results demonstrate the value of additional x-rays in cases of abnormal findings, as well as the need to improve radiographer techniques.

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34. 地域がん登録との照合によるがん検診の精度評価

～感度・特異度の測定～

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1　目的

大阪府がん登録と当センターの検診受診者ファイルとの記録照合を行ない、各がん検診の精度を評価し、がん検診の精度管理の向上をめざす。

2　対象

1996年（平成8年）から2002年（平成14年）までの約7年間に、当センターで実施した胃・大腸・子宮・乳がん一次検診受診者のうち、大阪府在住者約80万件。

3　方法

がん検診受診者ファイルと大阪府がん登録ファイルとを照合することにより、2003年までの胃・食道・十二指腸・直腸・結腸・子宮（頸部）・乳がん罹患患者を把握した。照合の同定指標は性、生年月日、氏名（カタカナ・漢字：氏名一文字目）、居住市町村コードとし、類似リストから、同一リストを抽出作成した。同一リスト該当者を当センター受診者ファイルに「がん登録」データを入力し、真のがん罹患を算出できるデータとした。

「がん登録照合」データを入力することにより、検診で「異常なし（精検不要）」と判定されたにかかわらず、新たにがんの罹患が確認された症例（偽陰性例）を把握して感度・特異度をもとめ、検診精度を評価した。

1）偽陰性の定義

各がん検診での一次検診で「異常なし」（精密検査不要）と判定されたものを陰性とみなした。検診日以降にがん登録データが入力され、「偽陰性（見落とし例）」と集計する期間は胃・大腸がん検診では検診日から1年未満、子宮がん乳がんは2年未満とした。

2）集計期間

集計は単年度（1月1日～12月31日）で行い、7年間分の合計で算出した。受診者数、判定結果ともに、延べ数集計である。

※複数回検診を受診しており、結果「異常なし」と判定された後、陰性定義の期間中にがん登録された場合はそれぞれを延カウントとした。

（表１）　偽陰性の定義

①胃がん（食道、十二指腸含む） 一次検診（胃Ｘ線検査）の総合判定（診断）で「異常なし」の判定後、1年未満に「胃がん（食道、十二指腸含む）」診断された症例の全数
②大腸がん 一次検診（便潜血反応検査）の総合判定（診断）で「陰性」の判定後、1年未満に「大腸がん」診断された症例の全数
③子宮（頸部）がん 一次検診（細胞診）のクラス分類ⅠもしくはⅡの判定後、2年未満に「子宮頸部がん」診断された症例の全数
④乳がん 一次検診（視触診のみ、視触診+エコー胃Ｘ線検査）の総合判定（診断）で「異常なし」の判定後、2年未満に「乳がん」診断された症例の全数 ※感度・特異度の算定には「要観察」は要精検と同扱いとした

4　結果

1）胃がん検診

当センター胃がん検診受診者ファイル 191,140 件（実人数）を照合し、胃がんとの診断にてがん登録されているデータ 1,365 件（胃がん 1,357、食道 8）を抽出した。

一次検診受診者総数は 431,101、要精検率 9.4%、精検受診率 89.5%、がん発見率は 0.17%であった。がん登録との照合によって初めて把握することができた精度管理指標をみると、感度 85.9%、特異度 90.7%、偽陽性 3,993 例（9.3%）、偽陰性 123 例（14.1%）であった。

今回の検討では、検診受診後一年以内にがんと診断された全ての患者と逐年検診で発見された全てのがん患者を偽陰性として扱った。本研究における検診の感度にはスクリーニング検査自体の診断精度の他、逐年受診者の割合が影響を及ぼしたと考えられる。研究対象期間の後半では、高濃度低粘性バリウムの開発に伴って撮影法が改良され、消化器がん検診学会が推奨する従来法（7 枚法）から新撮影法（8 枚法）に移行した時期にあたる。今後、新撮影法の評価を行うと共に、偽陰性症例のフィルムを振り返り、撮影や読影上の問題について検討する。

（表２）胃がん検診結果（平成８年～平成 14 年）

	集検受診	要精検	率	精検受診	率	結果がん	率	早期がん	率
異常なし	380,997	0	0.0%	0	0.0%	120	0.03%	0	
精検不要	9,415	0	0.0%	0	0.0%	3	0.03%	1	
不明・その他	2								
要精検A	187	187	100.0%	178	95.2%	144		18	
要精検 B	420	420	100.0%	393	93.6%	108		30	
要精検 C	3,702	3,702	100.0%	3,255	87.9%	140	0.17%	38	
要精検 D	30,097	30,097	100.0%	26,865	89.3%	300		98	
要精検 E	6,283	6,283	100.0%	5,723	91.1%	58		19	
合計	431,101	40,689	9.4%	36,414	89.5%	873	0.20%	204	0.05%
がん登録 無反映ﾃﾞｰﾀ	431,101	要精検率 （要精検 A-E）	9.4%	精検受診率 （要精検 A-E）	89.5%	がん発見率 （要精検 A-E）	750 人 0.17%	早期がん 割合	27.1%

注）要精検の分類 A:がん確診　B:積極的疑い　C:がん否定できず　D:良性病変二次疑い　E:二次読影判定異常なし

（表３）　胃がん検診精度評価（平成８年～平成 14 年）

		検診		
		陽性	陰性	計
がん	あり	750	123	873
	なし	39,939	390,289	430,228
	計	40,689	390,412	431,101

感度	750/873=85.9%
特異度	390,289/430,228=90.7%
偽陰性	123 例:14.1%
偽陽性	39,939 例:9.3%
陽性反応適中度	750/40,689=1.8%

２）大腸がん検診

当センター大腸がん検診受診者ファイル 101,310 件（実人数）を照合し、大腸がん診断にてがん登録されているデータ 557 件を抽出した。

一次検診受診者総数は 217,892 人、要精検率 4.3%、精検受診率 78.0%、がん発見率は 0.22%であった。精検受診率（78.0%）の低さは問題である。一次検診時の精検受診の重要性を伝える保健指導と要精検者への受診勧奨や受診行動への支援を強化したい。

がん登録との照合によって初めて把握することができた精度管理指標をみると、感度 79.5%、特異度 96.0%、偽陽性 8,793 例（4.0%）、偽陰性 123 例（20.5%）であった。偽陰性 80 例（65.0%）は検診システムにより早期がんであることが判明している。がん登録で初めて把握できた症例は死亡例（12 例）も含まれていたことから、進行がんであったこと考えられる。この対策として、当センターでは平成 13 年度より検査法を定性法(RPHA 法)から半定性法（ﾏｸﾞｽﾄﾘｰﾑ法）に変え、また、採便容器を乾式から緩衝液中で保存する湿式に変更するなどの改善を行った。今後も継続調査を行い、対象、追跡期間を延長してその効果について検討したい。

（表４）　大腸がん検診結果（平成８年～平成 14 年）

	集検受診	要精検	率	精検受診	率	結果がん	率	早期がん	率
陰性	208,623	0	0.0%	0	0.0%	123			
陽性	9,269	9,269	100.0%	7,232	78.0%	476	0.22%	310	
合計	217,892	9,269	4.3%	7,232	78.0%	599	0.27%	310	
がん登録無反映ﾃﾞｰﾀ	217,892	要精検率(陽性)	4.3%	精検受診率(陽性)	78.0%	がん発見率(陽性)	476 人 0.22%	早期がん割合	

（表５）　大腸がん検診精度評価（平成８年～平成 14 年）

		検診		
		陽性	陰性	計
がん	あり	476	123	599
	なし	8,793	208,500	217,293
	計	9,269	208,623	217,892

感度	476/599=79.5%
特異度	217,293/208,500=96.0%
偽陰性	123 例:20.5%
偽陽性	8,793 例:4.0%
陽性反応適中度	476/9,269=5.1%

3）子宮がん検診（頚部）

当センター子宮がん検診受診者ファイル 48,106 件（実人数）を照合し、子宮頸がん診断にてがん登録されているデータ 145 件を抽出した。

一次検診受診者総数は 84,674 人、要精検率 3.7%、精検受診率 89.1%、がん発見率は 0.10%であった。他部位のがん検診に比べて子宮がん検診は一見がん発見率が低くみえやすいが、子宮がん検診では「前がん状態（異形成）」での段階で治療されること少なくない。進行予防的治療が行われるのは子宮頚部がん検診の特徴である。

がん登録との照合によって初めて把握することができた感度と特異度の数値をみると、感度 95.4%、特異度 96.4%、偽陽性 3,080 例（3.6%）、偽陰性 4（4.6%）であった。他のがん検診と比較して、子宮がん検診においては、「陽性をより正確に陽性と判定」し、同様に「陰性をより正確に陰性と判定している」ことが示された。すなわち、子宮がん検診は精度の高い検診といえる。

更なる精度向上を目指し、偽陰性 4 例の事例を中心に検診試料を振り返り、診断検証を続ける。また、当センターでは平成 9 年 11 月頃より精検時に本人同意の下に HPV 抗体検査を実施し、結果を検診システムに入力している。平成 20 年度から子宮頸部がん検診の分類としてベセスダシステムが導入され、診断には HPV 感染の有無が不可欠になってくる。今回で得た、がん登録照合データに HPV 結果をクロスして今後の判定、診断に役立てたい。

（表６）子宮（頸部）がん検診結果（平成８年～平成 14 年）

	集検受診	要精検	率	精検受診	率	結果がん	率	早期がん	率
Ⅰ	4,548	0	0.0%	0	0.0%	1		0	
Ⅱ	76,962	0	0.0%	0	0.0%	3		0	
Ⅲa	2,991	2,991	100.0%	2,660	88.9%	36	0.10%	21	
Ⅲb	118	118	100.0%	106	89.8%	20		14	
Ⅳ	30	30	100.0%	30	100.0%	14		11	
Ⅴ	24	24	100.0%	21	87.5%	13		4	
不明･再検査	1	0	0.0%	0	0.0%	0		0	
合計	84,674	3,163	3.7%	2,817	89.1%	87	0.10%	50	0.06%
がん登録無反映ﾃﾞｰﾀ	84674	要精検率（Ⅲa-Ⅴ）	3.7%	精検受診率（Ⅲa-Ⅴ）	89.1%	がん発見率（Ⅲa-Ⅴ）	83 人:0.1%	早期がん割合	60.2%

（表７）　子宮（頸部）がん検診精度評価（平成８年～平成 14 年）

		検診		
		陽性	陰性	計
がん	あり	83	4	87
	なし	3,080	81,507	84,587
	計	3,163	81,511	84,674

感度	83/87=95.4%
特異度	81,507/84,587=96.4%
偽陰性	4 例:4.6%
偽陽性	3,080 例:3.6%
陽性反応適中度	83/3,163=2.6%

4）乳がん検診

当センター乳がん検診受診者ファイル 30,476 件（実人数）を照合し、乳がん診断にてがん登録されているデータ 323 件を抽出した。

一次検診受診者総数は 58,403 人、要精検率 5.5%、精検受診率 93.3%、がん発見率は 0.15% であった。

がん登録との照合によって初めて把握することができた精度管理の指標を見ると、感度 56.4%、特異度 92.6%、偽陽性 4,323 例（7.4%）、偽陰性 71 例（43.6%）であった。

当センターでは平成 13 年度から集団検診にﾏﾝﾓｸﾞﾗﾌｨｰ検診を導入した。今回の対象年度は平成 8 年から平成 14 年であり、対象年度の検査方法の大半が視触診・超音波検査（浸水法：ﾏｯﾄ 1）であった。ﾏﾝﾓｸﾞﾗﾌｨｰ併用検診が導入された平成 14 年度の精度管理の指標は、感度 88.9%、特異度 95.4、偽陽性 388 例（4.6%）、偽陰性 3 例（11.1%）であり、明らかに成績に差が生じている。今回の作業により、我々が採用していた乳がん検診の精度の低さを改めて認識することとなったが、今後、更に研究対象、期間を拡大し、検査方法別の精度やﾏﾝﾓｸﾞﾗﾌｨｰのｶﾃｺﾞﾘｰ分類別の精度を評価したい。

（表 8）乳がん検診結果（平成 8 年～平成 14 年）

	集検受診	要精検	率	精検受診	率	結果がん	率	早期がん	率
異常なし	53,985	0	0.0%	0	0.0%	71		0	
要観察	1,188	1,188	100.0%	0	0.0%	2		1	
要精検	3,227	3,226	100.0%	3,010	93.3%	90	0.15%	45	0.08%
不明/再検査	3	1	33.3%	0	0.0%	0		0	
合計	58,403	4,415	7.6%	3,010	68.2%	163	0.28%	46	0.08%
がん登録無反映ﾃﾞｰﾀ	58403	要精検率	5.5%	精検受診率	93.3%	がん発見率	90 人 0.15%	早期がん割合	60.2%

（表 9）　乳がん検診精度評価（平成 8 年～平成 14 年）

		検診 陽性	陰性	計
がん	あり	92	71	163
	なし	4,323	53,917	58,240
	計	4,415	53,988	58,403

感度	92/163=56.4%
特異度	53,917/58,240=92.6%
偽陰性	71 例:43.6%
偽陽性	4,323 例:7.4%
陽性反応適中度	92/4,415=2.1%

経費使途明細

事務用品費　（ﾃﾞｰﾀ出力用紙、インク代、事務消耗品、台帳用品、ラベル作成機　等）	¥48,200
印刷製本費　（印刷・製本・梱包・送料）	¥66,000
データファイルソフト（解析ソフト・プレゼンテーション・データ管理ファイル）	¥190,000
備品　（データ管理用キャビネット（鍵付）、合鍵作成　）	¥151,000
資料、参考文献費	¥44,800
合計	¥500,000

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Studies on High Concentration Barium Sulfate Used in Gastric Cancer Mass Screening

— Viscosity Change Dependent on pH and Temperature —

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Nowadays mass screening for gastric cancer is popularized in Japan. In the screening, gastric radiography is carried out using contrast medium, usually barium sulfate. Recently, high concentration barium sulfate has been developed and used in several medical facilities. However, high concentration barium sulfate flows out from the stomach faster than moderate concentration one used in the past, which happens to interfere with diagnosis. The flow rate is considered to depend on the viscosity of barium sulfate which changes based on gastric pH and temperature.

In this study, viscosity changes of barium sulfate with pH and temperature changes are examined on two types of high concentration one, 185B barium and 200C barium, and one type of moderate concentration one, 145A barium. The radiographs of gastric phantom applied with three types of barium sulfate are also tested in several conditions of pH and temperature. The results indicate that 185B barium is the best among three types for gastric radiography. The study on characteristics of barium sulfate may improve radiography technology in mass screening for gastric cancer.

Key Words: high concentration barium sulfate, viscosity, pH, temperature, mass screening for gastric cancer

I Introduction

Gastric cancer death rate in Japan is considerably high in the world [1]. The statistics in 2001 show that gastric cancer is the leading cause of death from all cancer for females (14.8%) and for males (17.8%) in Japan [2]. However, gastric cancer mortality is in decline perhaps as a result of mass screening using x-ray, the significance of which is appreciated [3-6]. In the screening, the subjects drink barium sulfate solution as a contrast medium. Recently high concentration media have been developed and indicated to be effective in many reports [7-10]. The Osaka Cancer Prevention and Detection Center has started to adopt high concentration barium sulfate since 2000 on the basis of new gastric roentgenography presented by the Japanese Society of Gastroenterological Mass Survey [11]. The availability of high concentration barium sulfate in mass screening has been recognized; it is superior in adhesion to gastric mucosa and satisfactory for mucosal visualization ability [12]. However, high concentration barium sulfate flows out fast from the stomach, which often interferes with diagnosis. The flow speed might be influenced by gastric form, physical position on radiography and the viscosity of barium sulfate. Yamagishi [13] reported the viscosity change with temperature and pH on sol and powder types of barium sulfate but not on high concentration one. Ogawa [14] examined only one type of low concentration barium sulfate.

In this study, any difference on viscosity is examined with recently used high concentration barium sulfate and past used moderate concentration one. Practically, viscosity changes with pH of artificial gastric juice (HCl) and temperature are studied on three types of barium sulfate (two types of high concentration ones and one type of moderate concentration one). X-ray radiographs of gastric phantoms applied by three types of barium sulfate are also taken and evaluated in quality.

II Materials and Methods

1. Contrast media

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

2. Viscosity measurement of contrast media

Viscosity of each medium was measured in the condition of various pH and temperature. Artificial gastric juice of pH0.8, pH1.2, pH1.6 and pH2.0 was made of HCl and distilled water. Only distilled water was pH7.7. Certain volume (40 ml) of artificial juice or water was mixed with 150 ml of each medium and the temperature of mixture was changed to 15 °C, 20°C, 25°C and 30°C. In every condition, viscosity was measured at 30 rpm by type B

viscometer (BH type, TOKIMEC Co., Ltd. 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. Measurements of pH were done using HORIBA pH meter D-52 (HORIBA, Ltd. Kyoto, Japan).

3. Radiographs of gastric phantom

Gastric phantom BMU-1 (Kyoto Chemistry Specimen Co., Ltd. Kyoto, Japan) was used and three types of contrast media containing artificial gastric juice of pH0.8, pH1.2, pH1.6 and pH2.0 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 Co., Ltd. Kyoto, Japan). The radiographs (PFH-T FILM Eastman Kodak Co., Ltd. Rochester, N.Y. U.S.A.) of gastric phantom were visually evaluated by seven examiners, five radiological technologists and two medical doctors.

4. Statistical analysis

The results were compared among groups by two-way analysis of variance (ANOVA). If significant, they were examined by Bonferroni-Dunn multiple comparisons post-hoc test. Spearman's correlation was used. Statistical analyses were performed using SPSS 11.5J (SPSS Japan Inc. Tokyo, Japan) for Windows.

Ⅲ Results

1. Viscosity

Viscosity changes by respective pH and temperature are shown in Fig. 1 on 145A barium, Fig. 2 on 185B barium and Fig. 3 on 200C barium. In every figure, it is shown that viscosity tends to decrease with pH increase and temperature increase. Viscosity of 145A barium is generally high, especially at pH0.8 and pH1.2. Compared with 145A barium, 185B barium and 200C barium are stable for changes of temperature and pH. Further, 185B barium is more stable than 200C barium.

Viscosity inversely correlates with pH for three types of barium sulfate (145A barium : r=-0.916, 185B barium : r=-0.901, 200C barium : r=-0.947).

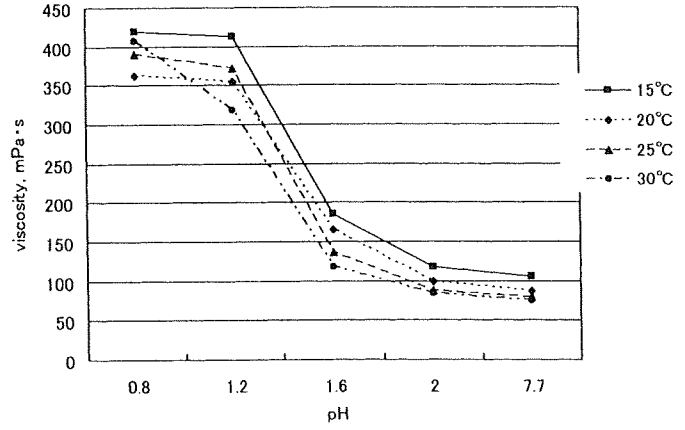

Fig. 1 Change of viscosity by respective pH and temperature (145A barium)

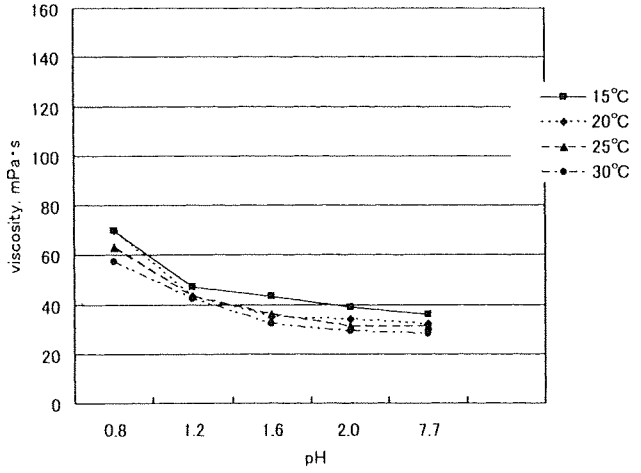

Fig. 2 Change of viscosity by respective pH and temperature (185B barium)

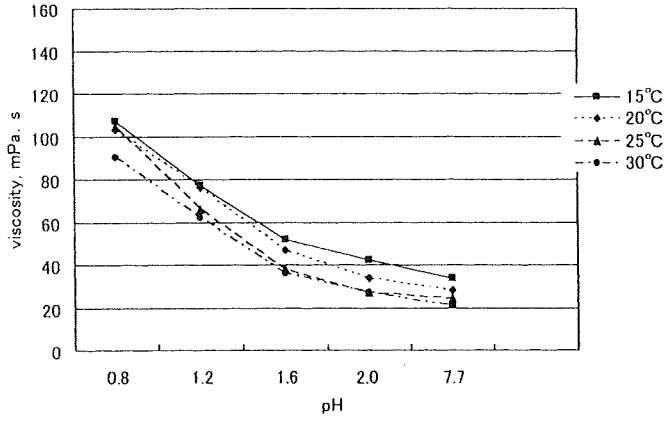

Fig. 3 Change of viscosity by respective pH and temperature (200C barium)

2. Radiographs

Radiographs of gastric phantom are shown in Fig.4 on 145A barium, Fig.5 on 185B barium and Fig. 6 on 200C barium. As shown in Fig.5, the appearance of 185B barium adhesion is almost same in spite of pH change. This result may be due to stable viscosity of 185B barium shown in Fig.2.

Alternatively, 145A barium or 200C barium adhesion is different for pH change, as shown in Fig.4 or Fig. 6. The visual evaluation of radiographs by seven examiners is that the mucosa adhesion of 185B barium is better than those of 145A barium and 200C barium.

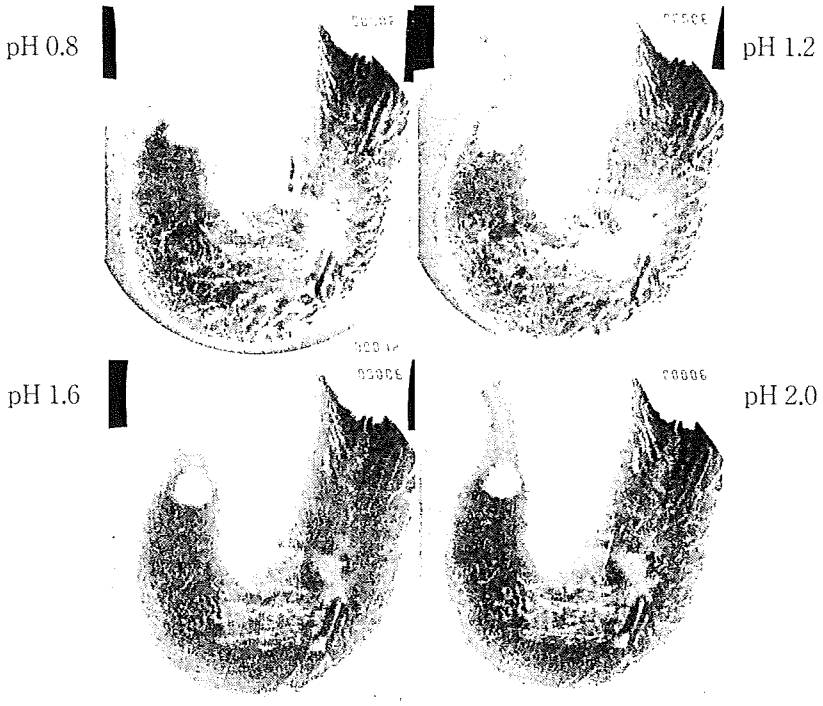

Fig. 4 Rediographs of gastric phantom (145A barium)

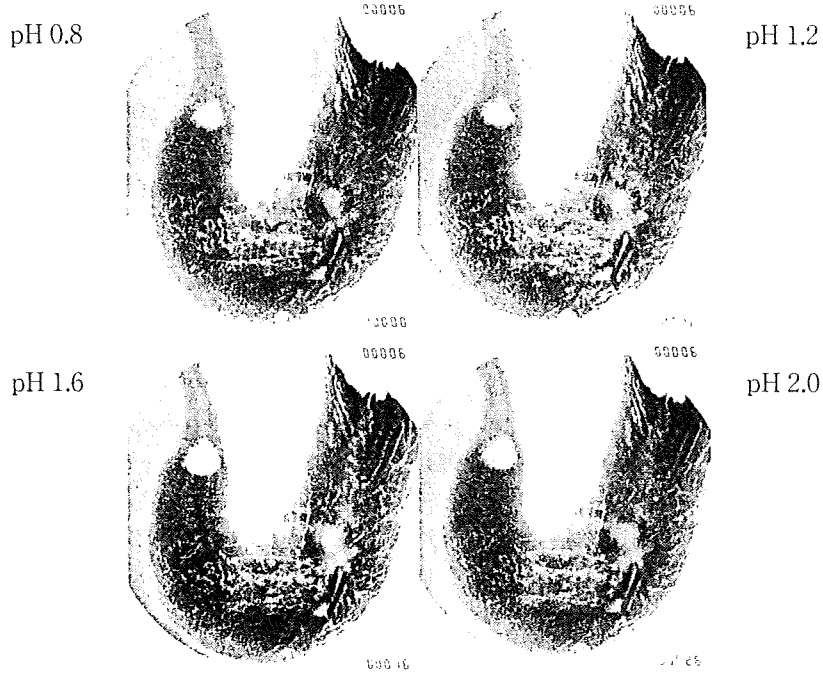

Fig. 5 Rediographs of gastric phantom (185B barium)

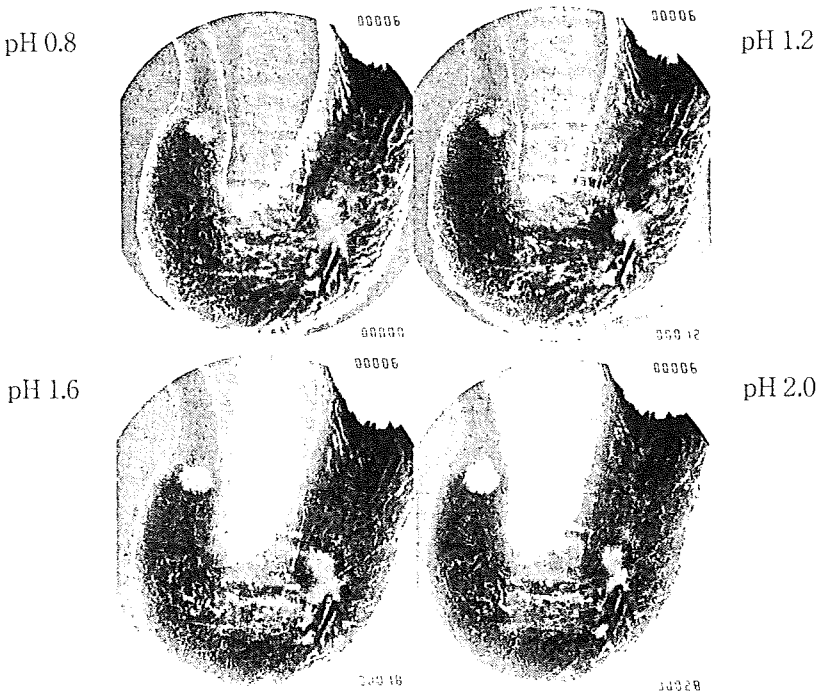

Fig. 6 Rediographs of gastric phantom (200C barium)

Ⅳ Discussion

The viscosity of contrast medium, barium sulfate, is an important factor in gastric radiography. 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 [11].

The study shows that the viscosity of barium sulfate is reduced with temperature increase. This result agrees with others [13, 14]. The influence of temperature on viscosity is more massive in powder type than in sol type [13]. In this study, 145A barium, a sol type of moderate concentration barium sulfate, is more affected on temperature than 185B barium and 200C barium, powder types of high concentration barium sulfate, as shown in Fig. 1-3. The difference between two results may be due to different pH and concentration of barium sulfate.

This study also denotes that the viscosity of barium sulfate is reduced with pH increase, as shown in Fig. 1-3. This result is consistent with others [13, 14]. The human gastric juice is usually at pH1.0-2.0 [15]. In this pH range, the viscosity change of 185B barium is less than those of 145A barium and 200C barium. The visual evaluation on radiographs of gastric phantoms shown in Fig.4-6, is that mucosa adhesion of 185B barium is better than those of 145A barium and 200C barium.

These results on viscosity changes of barium sulfate with pH and temperature and the visual evaluation on radiographs of gastric phantoms indicate that 185B barium is

preferable for examination in mass screening gastric cancer compared to 145A barium and 200C barium. Such study on characteristics of barium sulfate may contribute to technological improvement of radiographic mass screening for gastric cancer.

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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適性に関する研究
—pHと温度に依存する粘度変化—

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わが国で一般的に行われている胃がん検診では，造影剤として硫酸バリウム製剤が用いられる。近年，高濃度硫酸バリウム製剤が開発され，それを利用する施設が増えている。高濃度硫酸バリウム製剤は胃粘膜への付着性が良く有効性の報告があるが，一方では胃の外への流出が早く，十二指腸へ流れ出た場合は胃と重なり診断の妨げになることがある。本研究では，硫酸バリウムの流出は粘度に関係すると予測し，2種類の高濃度硫酸バリウムと従来から使用されている中濃度硫酸バリウムについて，温度と人工胃液(HCl)のpHを変化させた時の粘度変化を比較分析した。また，これら硫酸バリウム製剤を適用した胃ファントムを撮影し，画質の視覚評価も行った。その結果，高濃度硫酸バリウム185w/v%製剤はpHと温度の影響を受けにくく，粘度と画質が安定していることがわかった。硫酸バリウム製剤の特徴を分析することにより，胃撮影技術向上に貢献できると期待される。

キーワード：高濃度硫酸バリウム造影剤，粘度，pH，温度，胃がん検診