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ORIGINAL ARTICLE

Prospective Study

Long-term prognostic impact of circulating tumour cells in gastric cancer patients

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Abstract

AIM

To analyse the long-term prognostic impact of circulating tumour cells (CTCs) in gastric cancer patients who underwent surgery.

METHODS

A 7.5-mL peripheral vein blood sample was obtained from each patient with treatment-negative gastric adenocarcinoma before surgery. OBP-401, a telomerase-specific, replication-selective, oncolytic adenoviral agent carrying the green fluorescent protein gene, was used to label CTCs. Correlations between the number of CTCs and clinical end points were evaluated.

RESULTS

The median follow-up period of the surviving patients with gastric cancer was 60 mo. The CTC number tended to increase concomitantly with disease progression. The overall survival of patients with more than five CTCs in 7.5-mL of peripheral blood was lower than that of patients with five or less CTCs, although the difference was not significant (P = 0.183). A significant difference in relapse-free survival was found between patients with more than five and those with five or less CTCs (P = 0.034).

CONCLUSION

A lower number of CTCs was correlated with higher relapse-free survival rates in patients. Detection of CTCs using OBP-401 may be useful for predicting prognosis in gastric cancer.

Key words: Circulating tumour cells; Gastric cancer; Surgery; Telomerase; Prognosis

Core tip: We show the long-term prognostic impact of circulating tumour cells (CTCs) in 65 patients with gastric cancer in this report. OBP-401, a telomerase-specific, replication-selective, oncolytic adenoviral agent carrying the green fluorescent protein gene, was used to label CTCs. A lower number of CTCs was correlated with higher relapse-free survival rates in patients with gastric cancer.

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INTRODUCTION

The presence of circulating tumour cells (CTCs) in peripheral blood indicates a systemic disease stage in various malignancies, as CTCs are thought to be the source of haematogenous metastasis[1]. Detection of CTCs in peripheral blood is useful for prognosis, monitoring of disease progression, and evaluation of treatment efficacy in breast[2], lung[3], prostate[4], skin[5], colon[6], gastric[7], and esophageal cancer[8,9]. Although various methods have been developed to detect CTCs, the most commonly used techniques for their enrichment and characterisation are density gradient separation[10], immunomagnetic separation[11], flow cytometry[12], direct enrichment by filtration[13], and microchip technology[14]. The CellSearch System (Veridex, LLC, Raritan, NJ, United States), which is based on immunomagnetic cell enrichment, is one of the most widely used techniques for automated enrichment and detection of CTCs[15,16]. The advantage of immunomagnetic cell separation is that CTCs can be directly visualised under a microscope. In the CellSearch assay, cells detected with antibodies against epithelial markers (*e.g.*, epithelial cell adhesion molecules, or EpCAMs) are classified as CTCs. During the epithelial-mesenchymal transition (EMT), an important process that occurs in CTCs[17], expression of epithelial surface markers is reduced. Thus, systems that rely on epithelial markers may fail to detect CTCs undergoing EMT[18]. Methodologies based on direct enrichment by filtration may circumvent this issue to some extent, although cells detected in this manner often lack tumourigenicity.

Increased telomerase activity is a common characteristic of malignant tumours, and telomerase plays important roles in carcinogenesis and disease progression[19]. OBP-401 (TelomeScan, Oncolys BioPharma, Tokyo, Japan) is a telomerase-specific, replication-selective modified viral agent in which the human telomerase reverse transcriptase (*TERT*) gene promoter is inserted into the E1 region, and the green fluorescent protein (*GFP*) gene is placed under the control of the cytomegalovirus promoter in the E3 region as a marker of viral replication[20]. Thus, OBP-401 only proliferates in viable cells with high telomerase activity and provides a fluorescent label that allows tumour cells to be labelled, regardless of their epithelial marker expression profiles. We previously used OBP-401 to detect cells with high telomerase activity in blood samples of healthy and treatment-negative gastric cancer patients before surgery. We took 7.5-mL peripheral blood samples from cancer patients before surgery and healthy volunteers. We detected viable GFP-positive CTCs in the blood samples after incubation with OBP-401. This revealed that in patients with gastric cancer, a greater proportion of "high telomerase activity" cells was associated with a significantly poorer prognosis[21]. In this report, we describe the final long-term results (median follow-up time of five years) of this initial study, which demonstrate that the OBP-401-dependent CTC assay has clinical utility in patients with gastric cancer.

MATERIALS AND METHODS

Patients and healthy volunteers

This report was the final analysis of our prospective preliminary study on CTCs from 65 patients with treatment-negative gastric adenocarcinoma who underwent surgery at the Digestive Disease Center of the Showa University Northern Yokohama Hospital between April 2010 and May 2011, and from whom we extracted peripheral blood samples before treatment. The inclusion criteria were: (1) histologically proven adenocarcinoma of the stomach by endoscopic biopsy; (2) clinical solitary tumour; (3) no prior endoscopic resection, chemotherapy, or radiotherapy; (4) aged 20-80 years; (5) Eastern Cooperative Oncology Group performance status (Oken *et al*[22], 1982) of 0 or 1; (6) sufficient organ function; and (7) written informed consent. The exclusion criteria were: (1) synchronous or metachronous malignancy; (2) pregnant or breast-feeding women; (3) active or chronic viral hepatitis; (4) active bacterial or fungal infection; (5) diabetes mellitus; (6) systemic administration of corticosteroids; and (7) unstable hypertension. The pathologic stage of the disease was determined according to the seventh edition of the American Joint Committee on Cancer/ International Union Against Cancer TNM classification system[23]. The depth of the tumour invasion in four patients without gastrectomy and the regional lymph node status of seven patients without sufficient lymphadenectomy were surgically diagnosed.

All of the patients were checked regularly in our hospital every 3 mo for the first 3 years post-operation, and every 6 mo for the following two post-operative years. The patients also underwent endoscopy and computed tomography at least once a year, according to their disease stage and course. Healthy volunteers were also recruited as controls. All healthy volunteers were employees of Sysmex Corporation, which included seven men (mean age, 31.4 years; range, 24-39 years) and three women (mean age, 33.7 years; range, 26-48 years). All volunteers underwent medical check-ups upon employment and annually; check-ups included medical interviews, auscultation, chest radiography, and blood and urine analyses. In addition, individual interviews were conducted before sample collection; any volunteer who was currently receiving medical treatment, pregnant, or breast-feeding or who had donated blood within the past month was excluded.

Telomerase-specific viral agent

OBP-401, a telomerase-specific, replication-selective adenoviral agent in which the *TERT* promoter element drives the expression of the *EIA* and *EIB* genes and into which the *GFP* gene is integrated, was used. The sensitivity and specificity of the assay using OBP-401 have been reported previously[24]. Viral samples were stored at -80 ℃.

Sample preparation and immunostaining

Details of sample preparation and assay were described in our previous report[21]. A 7.5-mL peripheral vein blood sample was obtained from each patient before surgery and from each healthy volunteer. The samples were drawn into tubes containing citric acid, phosphoric acid, and dextrose, and stored at 4 ℃. The assay was started within 48 h of sample collection. The samples were centrifuged for 5 min at 540 × *g*, and the plasma phase was removed. The cells were then washed four times with phosphate-buffered saline (PBS) and twice with Roswell Park Memorial Institute medium. The samples were infected with 4×10^8 plaque-forming units of OBP-401 virus by incubation in the medium for 24 h at 37 ℃. Dead cells were stained with the red-fluorescent reactive dye L23102 (Life Technologies, Carlsbad, CA, United States), OBP-401 was inactivated, and the cells were fixed with 2% paraformaldehyde for 20 min at room temperature. The samples were treated with a surface-active agent (Emalgen 2025G; Kao Chemicals, Tokyo, Japan) for 10 min at 40 ℃ to degrade red blood cells. Phycoerythrin-labelled anti-human CD45 antibody (BioLegend, San Diego, CA, United States) was diluted 1:5, and Pacific Blue-labelled anti-human CD326 (EpCAM) antibody (BioLegend) was diluted 1:10 in PBS containing 2% foetal bovine serum. Cells were incubated with the diluted antibodies for 30 min at 25 ℃. After being washed with PBS containing 2% foetal bovine serum, the cells were mounted on two glass slides for microscopic analysis.

GFP fluorescence intensity of cultured cancer cell lines

Approximately 30000 cultured cells were added into 7.5-mL blood samples from healthy volunteers, which were mixed with various cancer cell lines: A549 (lung carcinoma), HepG2 (hepatocellular carcinoma), HEC-1 (endometrial carcinoma), KATO-III (gastric carcinoma), SBC-3 (small cell lung carcinoma), LNCaP (prostate adenocarcinoma), MDA-MB-468 (breast carcinoma), and OVCAR-3 (ovarian carcinoma). The cell lines were cultured according to the vendor's specifications.

Determination of GFP fluorescence intensity and cell size threshold

The threshold for GFP fluorescence intensity and cell size (diameter) were set based on the values from samples of healthy volunteers and the patients with gastric cancer by using receiver operating characteristic (ROC) analysis. The blood samples were subjected to the CTC detection assay, and GFP-positive cells were scored by fluorescence microscopy.

Cell counting and analysis

All detectable GFP-positive cells on the two slides were analysed under a computer-controlled fluorescence microscope (IX71, Olympus, Tokyo, Japan); the observer was blinded to the sample details. Cells with fluorescence intensities and diameters exceeding the threshold were scored as GFP-positive. Both EpCAM-positive and EpCAM-negative subpopulations

Table 1 Patient characteristics and clinical findings

Variable		Number of patients
Sex	Male	46
	Female	19
Age (yr; mean, range)		58.8; 33-76
Gastrectomy	Distal	29
	Total	32
	None	4
Surgical curability	R0	57
	R1	0
	R2	8
Clinical course	Survival without relapse	47
	Survival after relapse	2
	Survival after non-curative surgery	1
	Decease	15
Recurrence site (including overlap)	None	47
	Remnant stomach	1
	Hematogenous	5
	Lymphatic	4
	Peritoneal dissemination	5
	Non-curative surgery	8
Postoperative chemotherapy	None	37
	Adjuvant chemotherapy	11
	Adjuvant and therapeutic chemotherapy	9
	Therapeutic chemotherapy after non-curative surgery	8
TNM stage	I	40
	II	6
	III	10
	IV	9
Depth of tumour invasion	T1	36
	T2	8
	T3	9
	T4	12
Lymph node metastasis	N0	39
	N1	5
	N2	6
	N3	15
Distant metastasis	M0	56
	M1	9
Main histological type	Differentiated	25
	Undifferentiated	40
Lymphatic invasion	L0	35
	L1	26
	LX	4
Venous invasion	V0	35
	V1-2	26
	VX	4

were found in these cells, consistent with the finding that tumour cells undergoing EMT can be EpCAM-negative[18].

Institutional review board statement and clinical trial registration

The study was approved by the Institutional Review Board of the Showa University, Northern Yokohama Hospital (No. 0903-03). This study was registered with the University Hospital Medical Information Network in Japan, UMIN000004026.

Informed consent statement

The study protocol was explained to the patients and volunteers before written informed consent was obtained.

Statistical analysis

All statistical analysis was performed using JMP Pro 12.2.0 (SAS Institute, Cary, NC, United States). Non-parametric comparisons were performed using the Wilcoxon signed-rank test, with a normal approximation. ROC analysis was performed to examine the difference between *GFP* fluorescence intensity and cell size in the blood samples of patients versus those in healthy volunteers. Cox proportional hazards analysis was used to investigate risk factors for survival, and to calculate overall and relapse-free survival rates. $P \leqslant 0.05$ was considered statistically significant.

RESULTS

Patient characteristics and pathological findings

The clinicopathological characteristics of 65 patients (46 men and 19 women; mean age 60.7 years; range 33-76 years) are summarised in Table 1. The median follow-up period for the surviving patients was 60 mo. Fifty-seven of the 65 patients underwent pathological curative surgery, and of these patients, 10 experienced disease recurrence. Fifteen patients died. Twenty-nine patients had distal gastrectomy, 32 had total gastrectomy, and four had exploratory laparotomy. Twenty of the 57 patients that underwent curative surgery also received adjuvant chemotherapy, and nine of these 20 patients received therapeutic chemotherapy after disease recurrence.

Gallery of GFP-positive cancer cell lines after OBP-401 infection

After OBP-401 infection, GFP-positive cancer cell lines were detected (Figure 1A).

Comparison of GFP fluorescence intensity between cell lines and blood cells

The *GFP* fluorescence intensity [mean equivalent fluorochrome (MEFL)] of the cell lines and the GFP-positive cells detected in the peripheral blood samples are shown in Figure 1B. MEFL was higher in cell lines than in the GFP-positive cells in the peripheral blood samples from either healthy volunteers or patients with gastric cancer. In turn, MEFL was higher in GFP-positive cells from patients with gastric cancer than in the corresponding cells from healthy volunteers.

Comparison of GFP fluorescence intensity and cell diameter between patients and volunteers

The *GFP* fluorescence intensity and diameter of cells isolated from the peripheral blood samples are

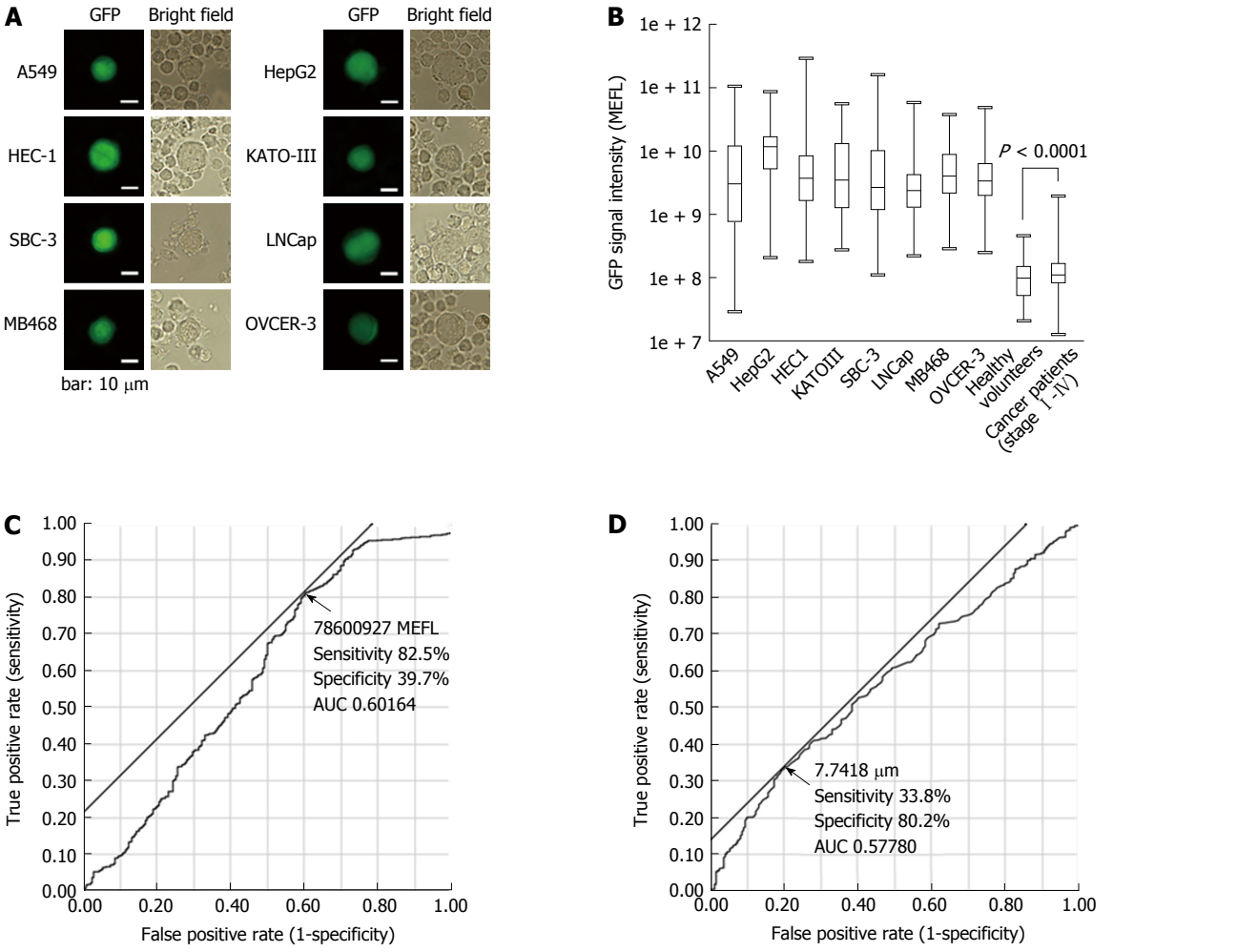

Figure 1 Comparison of green fluorescent protein fluorescence intensity and cell diameter. A: Gallery of GFP-positive cell lines. The cell lines used were A549, HepG2, HEC-1, KATO-III, SBC-3, LNCaP, MDA-MB-468, and OVCAR-3; B: Comparison of GFP fluorescence intensity of cultured cell lines and blood cells from healthy volunteers and gastric cancer patients. The bottom and top of the box represent the lower and upper quartiles, and the band across the box shows the median. The lower and upper bars at the ends of the whiskers show the lowest data point and the highest data point, respectively. The cell lines used were A549, HepG2, HEC-1, KATO-III, SBC-3, LNCaP, MDA-MB-468 and OVCAR-3; C: Comparison of GFP fluorescence intensity between patients and healthy volunteers; D: Comparison of cell diameter between patients and healthy volunteers. To determine the cut-off line, we used ROC analysis to compare the GFP fluorescence intensity and diameter of cells from gastric cancer patients with those of healthy volunteers. Cells from the patients with gastric cancer had higher GFP intensities than those from the healthy volunteers (cut-off 78600927 MEFL sensitivity 82.5 %, specificity 39.7 %, and AUC 0.602). The diameters of GFP-positive cells in samples from patients with gastric cancer were higher than those in samples from healthy volunteers (cut-off 7.7418 μm, sensitivity 33.8 %, specificity 80.2 %, and AUC 0.578). GFP: Green fluorescent protein.

shown in Figure 1C and D. Based on ROC analyses, we defined cells with 78600927 MEFL or higher GFP fluorescence intensity and 7.7418 μm or larger diameter as the CTCs.

Association of CTCs with pathological findings

An increased number of CTCs was associated with disease progression. There was statistically significant difference in the number of CTCs between samples from patients with Stage Ⅰ and those from patients with Stage Ⅲ disease (P = 0.0460, Figure 2A). The number of CTCs also tended to increase concomitantly with progression of the primary tumour, as there was a statistically significant difference in the number of CTCs between samples from patients with T1 and those from patients with T4 tumours (P = 0.0335, Figure 2B). There was also a statistically significant difference in the number of CTCs between samples from patients with N0 and those with N2 lymph node spread status (P = 0.0381, Figure 2C). However, there was no significant difference in the number of CTCs between samples from patients with distant metastases and those in which distant metastasis was absent (P = 0.4667, Figure 2D). The number of CTCs was also higher in samples from patients with lymphatic invasion, although there was no significant difference compared to patients without this clinical feature (P = 0.1297, Figure 2E). Similarly, although the number of CTCs in samples from the patients with venous invasion was higher than those in samples without this complication, the difference was not significant (P = 0.0558, Figure 2F). Finally, we observed no significant difference in the number of CTCs in samples from patients with differentiated tumours when compared to

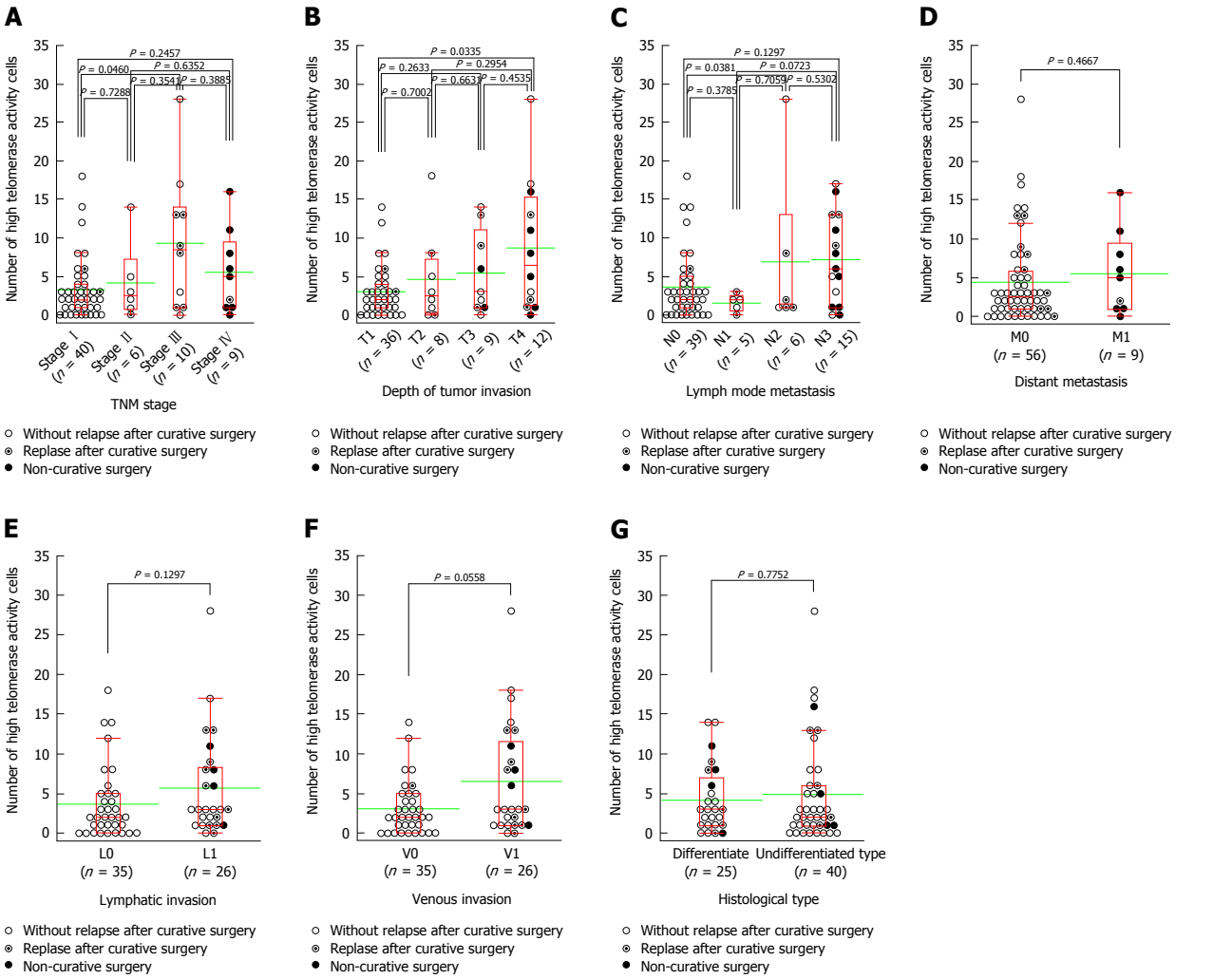

Figure 2 Relationship between circulating tumour cell number and pathological findings. Dots indicate the numbers of CTCs in each patient blood sample. The bottom and top of the box represent the lower and upper quartiles, and the band across the box shows the median. The lower and upper bars at the ends of the whiskers show the lowest data point within 1.5 interquartile ranges of the lower quartile, and the highest data point within 1.5 interquartile ranges of the upper quartile, respectively. The green bar shows the average. A: Disease stage (Stages 1-4 indicate disease progression); B: Depth of tumour invasion (T1-T4 indicate increasing depth); C: Lymphatic metastasis (N0-3 indicate number of metastatic lymph nodes); D: Distant metastasis (M0 = negative, M1 = positive); E: Lymphatic invasion (L0 = negative, L1 = positive); F: Venous invasion (V0 = negative, V1-V2 = positive); G: Histological type (differentiated and undifferentiated types). A: Relationship between CTC number and disease stage; B: Relationship between CTC number and T category. The number of CTCs tended to increase with progression of primary tumour. There was a statistically significant difference in the number of CTCs between samples from patients with T1 and those from patients with T4 status (P = 0.0335); C: The relationship between CTC number and N category. There was a statistically significant difference in the number of CTCs between samples from patients with N0 and those from patients with N2 classification (P = 0.0381); D: Relationship between CTC number and M category. There was no significant difference in the number of CTCs between samples from patients with distant metastases and those from patients without distant metastasis (P = 0.4667); E: Relationship between CTC number and lymphatic invasion. The number of CTCs in samples from patients with lymphatic invasion was higher than that in patients without invasion. However, this result did not reach the level of significance (P = 0.1297); F: Relationship between CTC number and venous invasion. The number of CTCs in samples from patients with venous invasion was higher than that in samples from patients without this pathology. However, this result did reach the level of significance (P = 0.0558); G: Relationship between CTC number and histological type. There was no significant difference in the number of CTCs between samples from patients with differentiated tumours and those from patients with undifferentiated tumours (P = 0.7752). CTCs: Circulating tumour cells.

those with undifferentiated malignancies (P = 0.7752, Figure 2G).

Overall and relapse-free survival

The overall survival rate of patients who had more than five CTCs (66.2%) was lower than that of patients who had five or less CTCs (80.5%); however, this difference was not significant (P = 0.183, Figure 3A). The relapse-free survival rate of patients who had more than five CTCs (64.3%) was significantly lower than that of patients who had five or less CTCs (88.3%) (P = 0.034, Figure 3B).

Prognostic factor for survival

We investigated prognostic factors related to patient survival by using Cox proportional hazards analysis. Univariate analysis showed that fStage was, in some cases, a significant factor (fStage Ⅱ, P = 0.196; fStage Ⅲ, P = 0.0003; fStage Ⅳ, P < 0.0001). In contrast, the presence of more than five CTCs was not a significant factor (P = 0.183). Multivariate analysis including these two factors showed fStage to be the

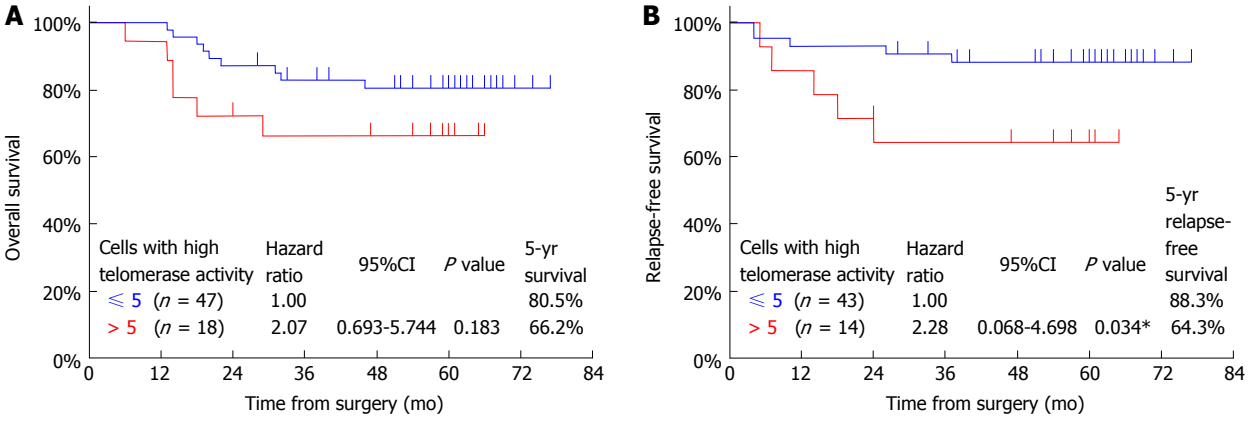

Figure 3 Overall and relapse-free survival. A: The overall survival rate of 65 patients was compared using Cox proportional hazards analysis. Although there was no significant difference, the overall survival rate of the patients with more than 5 CTCs was lower than that of patients with 5 or less CTCs (hazard ratio, 2.07; 95%CI: 0.693-5.744; *P* = 0.183); B: The relapse-free survival rates of 57 patients with different CTC levels who underwent curative surgery were compared using Cox proportional hazards analysis. Relapse-free survival was significantly lower in patients with more than 5 CTCs (hazard ratio, 2.28; 95% CI: 0.068-4.698; *P* = 0.034). CTCs: Circulating tumour cells.

Table 2 Risk factors for prognosis of patients (*n* = 65)

Variable	Univariate analysis			Multivariate analysis		
	Hazard ratio	95%CI	*P* value	Hazard ratio	95%CI	*P* value
Number of high telomerase activity cells						
≤ 5	1.0			1.0		
> 5	2.069	0.693-5.744	0.183	0.900	0.294-2.591	0.847
fStage						
fStage Ⅰ	1.0			1.0		
fStage Ⅱ	7.097	0.281-179.3	0.196	7.106	0.281-179.6	0.182
fStage Ⅲ	25.18	4.053-482.6	0.0003[b]	26.17	4.017-510.6	0.0004[b]
fStage Ⅳ	83.57	14.86-1567	< 0.0001[b]	85.76	14.91-1623	< 0.0001[b]

[b]*P* < 0.01.

only significant factor (fStage Ⅱ, *P* = 0.182; fStage Ⅲ, *P* = 0.0004; fStage Ⅳ, *P* < 0.0001), and the number of CTCs (more than five) to be non-significant (*P* = 0.847) (Table 2).

Risk factor for relapse after curative surgery

We also investigated factors for increased risk of relapse by Cox proportional hazards analysis. Univariate analysis showed that certain fStages were significant risk factors (fStage Ⅱ, *P* = 0.337; fStage Ⅲ, *P* = 0.0001; fStage Ⅳ, *P* = 0.005). However, the presence of more than 5 CTCs had no significant influence on relapse rates (*P* = 0.052). Multivariate analysis including these two factors showed fStage to be the only significant factor (fStage Ⅱ, *P* = 0.343; fStage Ⅲ, *P* = 0.001; fStage Ⅳ, *P* = 0.004), whereas the number of CTCs was non-significant (*P* = 0.350, Table 3).

DISCUSSION

Here, we used a telomerase-specific adenoviral agent to detect CTCs to avoid relying on the heterogeneous expression of epithelial markers in CTCs undergoing EMT. The enumeration of CTCs is particularly important in gastric cancer, which is the second leading cause of cancer-related death worldwide. Our current data indicate that detection of CTCs may indeed be a useful prognostic indicator for use in patients with gastric cancer, and are consistent with previous reports[25,26].

Our previous preliminary study showed that the number of CTCs isolated from cancer patients was related to surgical and pathological disease progression. Specifically, there were more CTCs in samples from patients with Stage Ⅲ than in those with Stage Ⅰ disease. The CTC count was also higher in patients with tumour depth T4 than in those with T1, and in individuals with lymph node metastasis status N2 versus those with N0. In addition, we found that the number of CTCs was associated with disease stage and relapse after curative surgery in gastric cancer patients. In the current study, the relapse-free survival rate of patients who had more than five CTCs was significantly lower than that of patients who had five or less. The overall survival rate of patients with more than five CTCs tended to be lower than that of the patients with five or less; in this case, however, the difference was not statistically significant. The number of CTCs was not an independent risk factor for either

Table 3 Risk factors for relapse of patients who underwent curative surgery (n = 57)

Variable	Univariate analysis			Multivariate analysis		
	Hazard ratio	95%CI	*P* value	Hazard ratio	95%CI	*P* value
Number of high telomerase activity cells						
≤ 5	1.0			1.0		
> 5	3.566	0.988-12.88	0.052	1.971	0.471-8.861	0.350
fStage						
fStage Ⅰ	1.0			1.0		
fStage Ⅱ	3.635	0.169-37.96	0.337	3.576	0.166-37.35	0.343
fStage Ⅲ	17.78	4.065-121.8	0.0001[b]	13.75	2.806-100.7	0.001[b]
fStage Ⅳ	239.6	7.943-7785	0.005[b]	289.4	9.331-9733	0.004[b]

[b]$P < 0.01$.

overall or relapse-free survival. However, we suggest this may be due to the relatively small sample size we studied, and that examination of larger cohorts might reveal a more significant impact of CTC number on these clinical parameters. Cancer stem cells (CSCs) in the blood of cancer patients are increasingly viewed as important determinants of cancer metastasis[27,28] and prognosis[29]. Given that CSCs have high telomerase activity, and share many of the molecular hallmarks of EMT[30], we suggest that our CTC assay could be used to detect both CSCs and CTCs during EMT.

One limitation of our study is that we could not achieve maximal sensitivity and specificity with regard to CTC detection. The definition of CTCs in this study was based on the threshold of GFP fluorescence intensity and cell diameter. However, these criteria resulted in a significant overlap between the data of healthy volunteers and those of cancer patients. More studies that compare healthy individuals with a larger population of patients with different cancer types are needed to clarify the suitability of CTC detection for clinical use. Another limitation of our study was that we did not determine the metastatic potential of the CTCs that we detected. Ideally, the functions of CTCs should be analysed after cell sorting, and CTCs with metastatic potential could be identified using additional tools such as DNA ploidy analysis[31,32]. Furthermore, gene expression profiling of CTCs, primary tumours, and metastatic tumours will also provide important insight into the mechanisms responsible for cancer metastasis. In summary, CTCs are useful predictors of disease progression in gastric cancer patients, but they do not constitute an independent prognostic factor.

In conclusions, CTC number tended to increase with surgical and pathological disease progression. Although not an independent risk factor, a higher number of CTCs was significantly correlated with disease relapse in gastric cancer after curative surgery. However, our study analysed only a small number of participants, and whether all the CTCs we detected have true metastatic potential was not determined. Further studies with a larger number of participants are therefore required to confirm the findings of this study.

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COMMENTS

Background

Detection of circulating tumour cells (CTCs) in peripheral blood is useful for prognosis, monitoring disease progression, and evaluation of treatment efficacy in malignancies, and various methods have been developed to detect CTCs.

Research frontiers

Most CTC detection systems that rely on epithelial markers may fail to detect CTCs undergoing the epithelial-mesenchymal transition.

Innovations and breakthroughs

Because OBP-401 is a telomerase-specific adenoviral agent, the OBP-401 assay does not depend on the expression of surface epithelial markers.

Applications

In this study, viable CTCs with high telomerase activity were detected using OBP-401 in blood samples from patients with gastric carcinoma. The authors showed that a lower number of CTCs correlated with higher relapse-free survival rates in patients with gastric cancer.

Terminology

The authors believe that the OBP-401 assay for detection of CTCs is clinically useful for patients with gastric carcinoma.

Peer-review

The authors presented a novel technique for detection of CTCs that does not depend on surface epithelial markers. The authors showed that a lower number of CTCs was correlated with higher relapse-free survival rates in patients with gastric cancer.

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