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SPARC Expression Did Not Predict Efficacy of nab-Paclitaxel Plus Gemcitabine or Gemcitabine Alone for Metastatic Pancreatic Cancer in an Exploratory Analysis of the Phase III MPACT Trial

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Results from a previous study suggested that SPARC might be a predictive efficacy biomarker for nab-P + Gem in MPC. These results led to SPARC being included as an exploratory endpoint in the phase III MPACT trial, which compared nab-P + Gem vs Gem alone for MPC. A SPARC assay was developed and used to examine samples, largely from metastatic lesions, from MPACT. In contrast with previous adjuvant PC studies, no significant association was observed between stromal SPARC level and efficacy in either treatment arm. No correlations were observed between plasma SPARC and efficacy in this study. Moreover, a preclinical experiment performed in mouse models of PC in which SPARC was intact or deleted demonstrated the same lack of association. The results of this exploratory analysis do not support the use of SPARC expression to guide treatment with nab-P + Gem or Gem alone in MPC.
Abstract

**Purpose:** *nab*-Paclitaxel plus gemcitabine was superior to gemcitabine alone for patients with metastatic pancreatic cancer (MPC) in the phase III MPACT trial. This study evaluated the association of Secreted Protein Acidic and Rich in Cysteine (SPARC) levels with efficacy as an exploratory endpoint.

**Experimental Design:** Patients with previously untreated MPC (*N* = 861) received *nab*-paclitaxel plus gemcitabine or gemcitabine alone. Baseline SPARC level was measured in the tumor stroma and epithelia (archival biopsies) and plasma. Experiments were performed in PC mouse models in which SPARC was intact or deleted.

**Results:** SPARC was measured in the tumor stroma of 256 patients (30%), the tumor epithelia of 301 patients (35%), and plasma of 343 patients (40%). Stroma-evaluable samples were from metastases (71%), the pancreas (11%), or of unidentifiable origin (insufficient tissue to determine; 17%). For all patients, stromal SPARC level (high [*n* = 71] vs. low [*n* = 185]) was not associated with overall survival (OS; hazard ratio 1.019; *P* = 0.903); multivariate analysis confirmed this lack of association. There was no association between stromal SPARC level and OS in either treatment arm. Neither tumor epithelial SPARC nor plasma SPARC were associated with OS. Results from a SPARC knockout mouse model treated with *nab*-paclitaxel plus gemcitabine revealed no correlation between SPARC expression and tumor progression or treatment efficacy.

**Conclusions:** SPARC levels were not associated with efficacy in patients with MPC. This exploratory analysis does not support making treatment decisions regarding *nab*-paclitaxel plus gemcitabine or gemcitabine alone in MPC based on SPARC expression.
Introduction

The field of pancreatic cancer (PC) treatment would greatly benefit from the identification of biomarkers to guide therapy selection. Unfortunately, current treatment guidelines do not indicate which of the few recommended treatments for metastatic PC (MPC) is most likely to benefit a given patient based on tumor biology (1).

Secreted Protein Acidic and Rich in Cysteine (SPARC), also known as BM-40 or osteonectin, was first reported by Sage et al in 1984 (2-4). Originally purified as an albumin-binding protein, SPARC was found to localize to the extracellular matrix and play roles in tissue remodeling, embryonic development, cell migration, and angiogenesis (2, 4-10). The role of SPARC in cancer is unclear, with most studies suggesting a protumorigenic role, but some suggesting an antitumorigenic role (11).

In PC, SPARC has been found to localize to tumor stroma, particularly fibroblasts and tumor epithelial cells (12). In a seminal retrospective analysis of patients with resectable PC (N = 299), Infante et al found that SPARC positivity in stromal fibroblasts was associated with worse overall survival (OS) compared with SPARC negativity (HR 1.89; 95% CI, 1.31–2.74; P = 0.001) (12). The presence of SPARC in tumor epithelial cells did not significantly associate with OS in that study.

A prospective phase III trial of patients with resectable PC (CONKO-001) demonstrated that those who received adjuvant gemcitabine (Gem) experienced a longer disease-free survival (DFS; median 13.4 vs 6.7 months; HR 0.55; P < 0.001) and OS (median 22.8 vs 20.2 months; HR 0.76; P = 0.01) than those who received no adjuvant therapy (13, 14). In accord with the Infante study, a recent subanalysis from CONKO-001 revealed that high stromal SPARC expression was associated with worse
DFS (median 9.0 vs 12.6 months, \( P = 0.005 \)) and OS (median 19.8 vs 26.6 months, \( P = 0.033 \)) compared with low stromal SPARC expression (15). In contrast to the Infante study, high SPARC in the tumor epithelia was also associated with worse DFS (median 7.4 vs 12.1 months, \( P = 0.041 \)) and OS (median 14.1 vs 25.6 months, \( P = 0.011 \)) compared with low SPARC. Stratified analyses demonstrated that the effects of stromal SPARC and epithelial SPARC were specific to patients who received Gem.

Because SPARC is known to bind albumin, it was hypothesized that SPARC in the tumor microenvironment may enrich the concentration of \textit{nab}-paclitaxel (\textit{nab}-P), an albumin-based formulation of paclitaxel, near tumors, possibly enhancing \textit{nab}-P antitumor activity (16). A potential link between SPARC expression and efficacy was observed in an exploratory analysis of a single-arm phase I/II study of patients with MPC treated with \textit{nab}-P plus Gem (17). However, in contrast to the studies described previously, this phase I/II trial showed that higher SPARC expression was associated with longer OS, although it must be noted that all patients were treated with \textit{nab}-P plus Gem. In this study, SPARC score was determined based on a complex methodology that entailed the use of 2 antibodies, 7 different tissue components, and 3 measures. The resulting 42 variables were each standardized through \( z \)-score analysis, a population-based measure, and scores from 2 pathologists were averaged. Patients with a high SPARC \( z \)-score (\( n = 19 \)) had a median OS of 17.8 months, whereas patients with a low SPARC \( z \)-score (\( n = 17 \)) had a median OS of 8.1 months (\( P = 0.043 \)). In addition, high SPARC staining in the stroma (\( P = 0.013 \)), but not in the tumor epithelia (\( P = 0.15 \)), was significantly associated with better OS.
The positive results from the phase I/II study described above, including a median OS of 12.2 months for patients treated at the maximum tolerated dose (17), led to the phase III MPACT study, which compared nab-P + Gem with Gem alone for the treatment of MPC (18). nab-P + Gem was superior to Gem alone for OS (primary endpoint; median 8.5 vs 6.7 months; HR 0.72; \(P < 0.001\)), progression-free survival (PFS; median 5.5 vs 3.7 months; HR 0.69; \(P < 0.001\)), and overall response rate (ORR; 23% vs 7%; \(P < 0.001\)) (18).

To follow up on the SPARC results from the preceding phase I/II study, the MPACT trial included SPARC analysis as an exploratory endpoint. A new clinical trial assay was developed to standardize and simplify the SPARC immunohistochemistry (IHC) assay. Here we describe the clinical trial assay, present the results of the exploratory SPARC analysis from the MPACT trial, and describe the effect of treatment with nab-P + Gem in a mouse model of PC in which the SPARC gene was deleted.
Patients and Methods

The patients and methods of the MPACT trial have been described previously (18). Key parameters and methods specific to this subanalysis are included below.

Patients

Eligible patients were ≥18 years of age, had confirmed measurable metastatic adenocarcinoma of the pancreas, had a Karnofsky performance status (KPS) of ≥70, and had not received prior chemotherapy for metastatic disease. SPARC biomarker collection was optional. Written consent was required for collection of samples and biomarker analysis. As a consequence, not all patients permitted examination of tumor samples.

Study design

Patients were randomized 1:1 (stratified by KPS, presence of liver metastases, and region) to receive nab-P 125 mg/m² plus Gem 1000 mg/m² on days 1, 8, and 15 every 28 days or Gem alone 1000 mg/m² on days 1, 8, 15, 22, 29, 36, and 43 every 56 days (cycle 1) and then on days 1, 8, and 15 every 28 days (cycle ≥2). Treatment continued until disease progression or unacceptable toxicity.

Statistical methods

The primary endpoint of the MPACT trial was OS. Secondary endpoints included PFS and ORR by independent evaluation. Correlation between SPARC findings and efficacy endpoints was an exploratory analysis of the MPACT trial intended to provide a better understanding of the utility of SPARC as a biomarker in MPC. The study was not powered to test the hypothesis of an association between SPARC and efficacy. Cox
regression models were used to investigate the correlation of OS with different SPARC variables. Multivariate analyses were performed to assess the influence of the following on OS (conducted using a Cox proportional hazards model with stepwise procedure): treatment group, age, sex, KPS, geographic region, primary tumor location, presence of biliary stent, previous Whipple procedure, presence of liver metastases, presence of pulmonary metastases, peritoneal carcinomatosis, stage of diagnosis, number of metastatic sites, CA 19-9 level at baseline, and SPARC score. Correlations between percentage changes in plasma SPARC from baseline and OS were examined by landmark analysis with the Cox regression model.

**SPARC IHC assay development**

IHC methods for 3 commercially available antibodies were optimized and tested to select the most appropriate one for assay development (ON1-1 [Invitrogen, Camarillo, California], 15G12 [Novocastra, Buffalo Grove, Illinois], and a polyclonal rabbit antibody [Sigma-Aldrich, St Louis, Missouri]). The ON1-1 monoclonal antibody used in the Infante et al study (12) was chosen because it provided the most intense staining in tumor epithelial and stromal cells (19).

SPARC staining was based on a modification of the accepted scoring methodology for human epidermal growth factor receptor-2 (HER2) in gastric cancer (20) and scored in 2 separate compartments: peritumoral stromal SPARC in fibroblasts, and tumor epithelial SPARC. Stromal staining was very high and homogeneous in positive fibroblasts; therefore, the score was based solely on the percentage of fibroblasts stained. An IHC score of 3+ corresponded to staining observed in ≥50% of cells readily identifiable at magnification of 20× to 40×; IHC 2+ corresponded to staining
observed in 25% to 49% of cells identifiable at magnification of 100× to 200×; IHC 1+ corresponded to staining observed in <25% of cells requiring magnification of up to 400×; IHC 0 corresponded to complete absence of staining. An IHC score of 3+ was interpreted as high staining, and scores ≤ 2+ were interpreted as low staining. Tumor epithelial SPARC was scored using a modified histoscore (H-score) as the percentage of positive cells × the staining intensity. An H-score ≥100 = high-positive; an H-score <100 = low-positive; absent = negative. Representative stainings for stroma and tumors are shown in Supplemental Figure S1.

**Plasma SPARC**

Plasma SPARC was evaluated at baseline and every 8 weeks by sandwich enzyme-linked immunosorbent assay (ELISA; Human SPARC Quantikine ELISA Kit; R&D Systems; Minneapolis, Minnesota) per the manufacturer’s instructions and reported as ng/mL of plasma. Changes of plasma SPARC levels from baseline to cycle 2 or 4 were summarized descriptively.

**Preclinical models**

**Elas-tTA/tetO-Cre; K-Ras<sup>+/LSLG12Vgeo</sup>; p53<sup>flox/flox</sup>** mice, which have been shown previously to develop pancreatic carcinoma (21), were crossed with the fully viable SPARC-null SPARC<sup>tm1Hwe</sup> mice from the Jackson Laboratory to generate tumor-bearing mice with the SPARC protein present (SPARC<sup>+/+</sup> or SPARC<sup>+/−</sup>) or absent (SPARC<sup>−/−</sup>). To examine tumor accumulation of paclitaxel, mice were treated with nab-P (formulated with human albumin; 25 mg of paclitaxel/kg) once the tumors reached a volume of 150 to 250 mm<sup>3</sup> (measured by ultrasound). Three hours after drug administration, tumors were harvested and homogenized in 4 volumes of Milli-Q water (EMD Millipore,
Billerica, Massachusetts). Homogenates were centrifuged and supernatants were treated to precipitate proteins and extract phospholipids in order to reduce potential matrix effects. Paclitaxel was then quantified by means of high-performance liquid chromatography (Agilent 1200; Agilent Technologies, Santa Clara, California) coupled with a triple quadrupole mass spectrometer (API2000; Applied Biosystems, Foster City, California), interpolating the peak area in a calibration curve made using tissue homogenates from untreated mice.

\[ SPARC^{+/+} \text{ and } SPARC^{tm1Hwe} \] mice were orthotopically implanted with cells from the PC cell line Panc02 (22) and followed for OS. Two days after implantation, mice were allocated to the following treatment groups: control (vehicle), \( nab-P \) (50 mg of paclitaxel/kg given intravenously once per week \( \times \) 3), Gem (100 mg/kg intraperitoneally given twice per week \( \times \) 3), or the combination of \( nab-P + Gem \) at the same doses and schedules. To protect animals from lethal anaphylactic shock due to the administration of \( nab-P \) formulated with human albumin, each mouse was treated with 50 μg of dexamethasone 48, 24, and 2 hours prior to administration of drug or vehicle.

Masson trichrome staining and immunohistochemistry was carried out on formalin fixed paraffin-embedded tumor samples from \( Elas-tTA/tetO-Cre; K-Ras^{+/LSLG12Vgeo}, p53^{flox/flox} \), \( SPARC^{+/+} \) or \( SPARC^{tm1Hwe} \) mice using the following antibodies: anti-mouse SPARC (MAB 942; R&D Systems), anti-cytokeratin-19 (TROMA-III; Monoclonal Antibodies Core Unit, Centro Nacional de Investigaciones Oncologicas [CNIO] Madrid, Spain), anti-collagen I (600-401.103; Rockland, Limerick, Pennsylvania), anti-alpha smooth muscle actin (RB-9010-PO, Thermo Scientific, Waltham,
Massachusetts), and anti-vimentin (5741; Cell Signaling Technology, Beverly, Massachusetts).

IHC and paclitaxel concentration comparisons were evaluated for significance using the unpaired Student’s t test. Kaplan-Meier plots were analyzed for significance using the log rank test. All calculations were performed using GraphPad Prism 5 software (GraphPad Software, La Jolla, California).
Results

Assay development

To evaluate robustness of the new SPARC IHC staining methodology, resection specimens from 50 patients not enrolled in this trial were analyzed by 3 pathologists using the new assay. Concordance of all SPARC scoring criteria was found to be 90%, suggesting a high degree of consistency in scoring (19). In addition, 31 of the 36 archival samples from the earlier phase I/II study were evaluated by the new SPARC assay. Nine of these samples did not have tumor tissue or tumor stroma on the slide, leaving 22 for comparison with the previous method. The tissues were collected from the pancreas (n = 7), liver (n = 5), not specified (n = 8), lung (n = 1), and small bowel (n = 1). A high degree of SPARC scoring concordance was observed (86%), and the significantly longer survival of high-SPARC patients was reproduced using the new assay.

Biomarker samples

Tissue collection for biomarker analysis was not mandatory in the MPACT trial. Biomarker samples were collected from 375 patients (Fig. 1). Stromal SPARC was evaluable in samples from 256 patients. Tumor epithelial SPARC was evaluable in 301 patients, and plasma SPARC was evaluable in 343 patients. The stroma- and tumor epithelia–evaluable samples were collected from the pancreas (11% and 10%, respectively), metastases (71% and 64%), and locations that were not identifiable by pathologists based on tissue morphology because of insufficient tissue (17% and 27%).

Stromal SPARC
Baseline characteristics were well balanced between treatment arms for patients with stroma-evaluable samples and were consistent with those of the intent-to-treat (ITT) population (Supplemental Table S1). Of the 131 patients in the nab-P + Gem arm with evaluable stromal SPARC, samples from 34 patients (26%) were classified as high SPARC and samples from 97 patients (74%) were classified as low SPARC. In the Gem-alone arm (n = 125 patients with stroma-evaluable samples), samples from 37 patients (30%) were classified as high SPARC and those from 88 (70%) were classified as low SPARC.

In a pooled-treatment-arm analysis, stromal SPARC score did not correlate with OS (Fig. 2). The median OS for patients with high vs low stromal SPARC scores was 8.0 vs 7.6 months (HR 1.019; 95% CI, 0.750–1.386; P = 0.903). Furthermore, a multivariate analysis revealed that stromal SPARC score did not appear to be an independent predictor of OS. Consistent with the primary report of the ITT analysis (18), treatment, KPS, and the presence of liver metastases were significant independent predictors of OS (Table 1) in this exploratory analysis. In agreement with the OS analyses, stromal SPARC score did not correlate with PFS or ORR.

In addition, the exploratory analysis revealed a lack of significant association between stromal SPARC score and OS within either treatment arm (Fig. 3). In the nab-P + Gem arm, the HR for OS in patients with high vs low SPARC was 1.505 (95% CI, 0.978–2.315). In the Gem-alone arm, the HR for OS in patients with high vs low SPARC was 0.658 (95% CI, 0.423–1.023). Among patients with high stromal SPARC, the nab-P + Gem group had more patients than the Gem group with a KPS of 70 to 80 (50% vs 32%) and liver metastases (94% vs 81%), both of which appeared to be significant
predictors of shorter OS in this analysis (Fig. 3; Table 1). A multivariate analysis within
the nab-P + Gem arm, which included SPARC level, KPS, and the presence of liver
metastases, did not identify SPARC level as a significant independent predictor of OS
(HR 1.395; 95% CI, 0.904–2.153; \( P = 0.133 \)).

**Tumor SPARC**

Baseline characteristics between treatment arms in the tumor epithelial SPARC-
evaluable population were well balanced (Supplemental Table S2). The majority of
evaluable samples had low or negative SPARC staining in the tumor epithelia (97%);
samples from only 10 of 301 patients had high SPARC (3%). There was no significant
correlation between tumor epithelial SPARC score and OS. The HR for high vs low
SPARC was 1.16 (95% CI, 0.52–2.62). Multivariate analysis revealed that tumor
epithelial SPARC did not appear to be a significant independent predictor of OS.

**Plasma SPARC**

The baseline characteristics between treatment arms in the plasma SPARC
evaluable population were well balanced (Supplemental Table S3). There was no
correlation between baseline plasma SPARC level and baseline SPARC level in the
tumor or stroma. (Supplemental Figure S2, Table S4). In addition, there were no
significant changes in plasma SPARC from baseline to cycle 2 or cycle 4 of the
treatment (Supplemental Table S5). Furthermore, neither baseline plasma SPARC nor
change from baseline appeared to be a significant independent predictor of OS by
multivariate analysis.

**Preclinical experiments in SPARC knockout mice**
To determine if SPARC might play a role in tumor development or progression, we generated genetically engineered compound mice that ubiquitously lack SPARC and develop PC: Elas-tTA/tetO-Cre; K-Ras^{+/LSLG12Vgeo}, p53^{flox/flox}, SPARC^{-/-} (further referred to as SPARC^{-/-}). There were no histologic differences observed between the tumors that developed in SPARC^{-/-} mice compared with SPARC^{+/+} littermate controls (Fig. 4A). OS was also examined in these animals. No difference in OS was observed between SPARC^{-/-} and SPARC^{+/+} or SPARC^{+/-} control animals (Fig. 4B). To investigate whether SPARC expression could affect the intratumoral accumulation of nab-P, SPARC^{+/+}, SPARC^{+/-}, and SPARC^{-/-} tumor-bearing animals were treated with a single dose of nab-P. Similar levels of paclitaxel were observed in the tumors of all 3 genotypes, suggesting that tumor penetration of nab-P is SPARC independent (Fig. 4C).

To determine whether, despite equal nab-P intratumoral accumulation, SPARC might be involved in tumor sensitivity upon long-term treatment with nab-P, we generated a second tumor-bearing animal model in which SPARC-null mice (Sparc^{tm1Hwe}) were orthotopically implanted with the PC cell line Panc02. Treatment with nab-P, Gem, or the combination each led to similar OS in SPARC-null mice compared with the same treatment in SPARC wild-type littermate controls, although there were differences between treatments. These data suggest that the activity of nab-P is independent of SPARC expression (Fig. 4D).
Discussion

This exploratory analysis represents the largest work to date \((n = 256)\) for stromal
SPARC) on SPARC in a clinical trial of patients with MPC. The results of this
exploratory analysis from MPACT suggest that there is no relationship between SPARC
levels and OS in patients with MPC treated with either \(nab\)-P + Gem or Gem alone.
Furthermore, a multivariate analysis within the \(nab\)-P + Gem arm, which included
SPARC level, KPS, and the presence of liver metastases (KPS and liver metastases
were included because they were significant, independent predictors of OS in the
primary efficacy analysis \([18]\) ), did not identify SPARC as an independent predictor of
survival. Two preclinical models of PC, one a genetically engineered mouse model and
the other an orthotopic model, also revealed no significant difference in the efficacy of
\(nab\)-P treatment based on the presence or absence of SPARC. These preclinical results
were consistent with those of a previous study that was conducted by Neesse and
colleagues in a different genetically engineered mouse model of PC \((23)\). Agreement of
the SPARC analysis in the MPACT trial with these independent mouse studies
strengthens the conclusion that the activity of \(nab\)-P was not influenced by SPARC
level.

The lack of association between SPARC expression and OS in this post hoc
exploratory analysis of patients with metastatic disease stands in contrast to results
reported from the CONKO-001 study and the Infante et al study in resectable PC \((12,\)
15). In fact, the CONKO-001 study demonstrated worse efficacy with Gem treatment in
patients with high vs low SPARC expression \((15)\), whereas this finding was not
observed in our analysis of patients being treated for metastatic disease. One of the
differences among these studies was the assay used to evaluate SPARC. The Infante et al study of resectable PC used the same antibody as the present study (ON1-1), but employed a more lenient scoring system for positivity (12). The CONKO-001 trial used a different antibody (Novocastra clone 15G12) and a more complex scoring system (15). Another difference of note was the source of the analyzed tissue. For both the Infante and CONKO-001 studies, pancreatic lesions were evaluated (12, 15), whereas only 11% of tissues from the MPACT trial were confirmed to be pancreatic lesions, with the remaining being either metastatic tissues or from regions that could not be identified.

It has been noted in other studies that SPARC expression can differ between primary and metastatic lesions (24, 25). In a study of PC, extensive SPARC immunostaining was present in the neoplastic epithelial cells of primary lesions, in contrast to weak or absent SPARC immunostaining in neoplastic cells of metastatic tissues (26). One possible mechanism for downregulation of SPARC expression is DNA methylation: the SPARC gene has been shown to be epigenetically silenced in numerous PC cell lines and in most xenograft tumors established from human primary pancreatic carcinomas (27). Among SPARC's many potential protumorigenic qualities is its ability to promote tumor cell migration and invasiveness, and suppression of SPARC expression has been found to reduce tumor cell adhesive and invasive capacities (26, 28). This potentiation of migration and invasiveness may come at the cost of reduced proliferation, as excess SPARC has been shown to inhibit cancer cell proliferation (26, 28). Enhanced SPARC expression may therefore be important for the metastatic process, but may be silenced in metastatic cells to allow for establishment of metastatic lesions.
The difference in SPARC results between this analysis of the MPACT phase III study and that of the phase I/II study which preceded it (17) prompts an evaluation of differences in trial design and methodology. One substantial difference between the 2 studies was the number of patients analyzed—specifically, stromal SPARC was evaluable in 256 patients in the MPACT trial vs 36 patients in the phase I/II trial. In addition, 7% to 8% of patients in the MPACT trial had a KPS of 70 compared with no patients in the phase I/II trial (17, 18). As noted previously, the origin of the evaluated tissue is also important to consider: 11% of samples in the MPACT trial vs 44% in the phase I/II trial were from primary pancreatic tumors. Finally, the differences in the IHC assays used in the phase I/II and MPACT studies are unlikely to have been a major contributor to the disparate SPARC results, as 86% concordance was observed between the 2 assays on a set of samples from 22 of the 36 patients in the phase I/II study.

As is the case with many biomarker-related evaluations, this study had some limitations. For example, SPARC biomarker collection was optional, and not all patients permitted examination of tumor samples. In addition, SPARC analysis was an exploratory endpoint of the trial; therefore, the study was not specifically designed to test the hypothesis of an association between SPARC level and treatment efficacy. A consequence of this is that the method of tissue collection for SPARC analysis was not specified in the protocol with respect to amount and location of tissue. Many of the samples that were analyzed were fine-needle aspirates that included little tumor stroma. Thus, although 861 patients were enrolled in the trial, SPARC analysis was only possible in a subset of patients; stromal SPARC was evaluated in 30% of patients.
Furthermore, the scoring methodology was not pre-defined. Analyses based on a different scoring methodology, in which patient samples were analyzed in 4 independent groups (IHC 0, 1+, 2+, and 3+) and IHC 0 and 1+ compared to IHC 2+ and 3+, or IHC 0, 1+ and 2+ compared to IHC 3+ as opposed to the high vs low classification were also conducted. In multivariate analysis, this methodology resulted in a similar lack of association between SPARC level and OS, PFS, or ORR. The need remains for useful biomarkers to guide treatment in PC, and robust preclinical experiments will be necessary to identify other potential markers to be tested in prospective trials.

Based on the results of this exploratory analysis, SPARC is not confirmed as a useful biomarker in selecting patients with MPC to receive nab-P + Gem or Gem alone. Current treatment selection in MPC is not based on the status of any particular biomarker (1). CA 19-9 has been used as a diagnostic and prognostic marker, but no data exist to suggest that patients with a particular level of CA 19-9 would benefit from one treatment over another (1). Human equilibrative nucleoside transporter (hENT1) has demonstrated some promise in predicting response to Gem in the adjuvant setting (29, 30); however, the only prospective study to date of hENT1 in patients with MPC revealed no association of hENT1 level with efficacy (31). A number of other biomarkers, such as carcinoembryonic antigen (CEA), pancreatic antioncofetal antigen, tissue polypeptide antigen, and cancer antigen 125 (CA 125), have been studied in PC (1), but more research is needed to validate their utility.

The SPARC assay that was developed for this study was simple and reproducible, and showed high concordance with the more complex assay that was used in the phase I/II trial (17). Unlike the phase I/II study, this SPARC analysis of
primarily metastatic biopsies revealed no prognostic or predictive value of SPARC level in patients who were being treated for MPC. A preclinical study also suggested that the effect of \textit{nab}-P--based treatment was not dependent on the presence of SPARC. The results of this exploratory analysis do not support the use of SPARC expression level for clinical decision-making regarding \textit{nab}-P + Gem or Gem alone in MPC.
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Author contributions

MH, JT, and DVH contributed to the concept and design of the manuscript, acquisition of data, analysis and interpretation, revising the manuscript for critically for important intellectual content, and final approval of version to be published. MM, CM, and PPL-C contributed to the concept and design of the preclinical studies, acquisition of data, analysis and interpretation, revising the manuscript for critically for important intellectual content, and final approval of version to be published. CP, PI, CBB, CH, DP, JT, and FLR contributed to the acquisition of data and analysis and interpretation, revising the manuscript critically for important intellectual content, and final approval of version to be published. AR and XW contributed to the concept and design of the study and analysis and interpretation, revising the manuscript critically for important intellectual content, and final approval of version to be published.
Figure Legends

Figure 1. SPARC biomarker sample collection in the MPACT study. Schematic representation of biomarker evaluable samples. C, cycle; D, day.

Figure 2. Relationship of stromal SPARC with OS. Kaplan-Meier analysis of OS in a pooled-treatment-arm analysis based on SPARC level.

Figure 3. Relationship of stromal SPARC and OS within each treatment arm. Kaplan-Meier analysis of OS based on SPARC level (high vs. low) and treatment arm.

Figure 4. Characterization of tumors, paclitaxel accumulation, and OS in $SPARC^{+/+}$ and $SPARC^{-/-}$ mice. (A) Immunohistochemistry in tumors from $Elas-tTA/tetO-Cre; K-Ras^{+/+}LSLG12Vgeo, p53^{flox/flox}$ mice with wild-type ($SPARC^{+/+}$) or null SPARC ($SPARC^{-/-}$). Pixel positivity was quantified. Ck-19, cytokeratin 19; αSMA, α smooth muscle actin. (B) Kaplan-Meier analysis of OS in $Elas-tTA/tetO-Cre; K-Ras^{+/+}LSLG12Vgeo, p53^{flox/flox}$ mice in which SPARC was wild-type ($SPARC^{+/+}$), heterozygous ($SPARC^{+/−}$), or knocked out ($SPARC^{-/-}$). (C) $SPARC^{+/+}, SPARC^{+/−},$ or $SPARC^{-/-}$ tumors from $Elas-tTA/tetO-Cre, K-Ras^{+/+}LSLG12Vgeo, p53^{flox/flox}$ mice that were treated with nab-P were harvested and tested by mass spectrometry to determine the concentration of paclitaxel. Differences between tumor concentrations were analyzed by unpaired 2-sided t test. (D) Kaplan-Meier analysis of OS in $SPARC^{+/+}, SPARC^{+/−},$ and $SPARC^{-/-}$ mice that had been implanted with Panc02 cells and treated with nab-P, Gem, or the combination.
References


Randomized Intent-to-treat Population
\((N = 861)\)

Randomized to 
\(nab\)-Paclitaxel + Gemcitabine
\((n = 431)\)

Treated with 
\(nab\)-Paclitaxel + Gemcitabine
\((n = 421)\)

Randomized to Gemcitabine
\((n = 430)\)

Treated with Gemcitabine
\((n = 402)\)

**Evaluable Samples**

- Baseline Plasma Sample
  \((n = 188)\)
- C2D1 Plasma Sample
  \((n = 115)\)
- C4D1 Plasma Sample
  \((n = 83)\)
- C6D1 Plasma Sample
  \((n = 56)\)
- C8D1 Plasma Sample
  \((n = 30)\)

Tissue Sample Available
\((n = 195)\)

Tumor SPARC Evaluable
\((n = 157)\)

Stromal SPARC Evaluable
\((n = 131)\)

**Evaluable Samples**

- Baseline Plasma Sample
  \((n = 155)\)
- C2D1 Plasma Sample
  \((n = 82)\)
- C4D1 Plasma Sample
  \((n = 58)\)
- C6D1 Plasma Sample
  \((n = 25)\)
- C8D1 Plasma Sample
  \((n = 12)\)

Tissue Sample Available
\((n = 180)\)

Tumor SPARC Evaluable
\((n = 144)\)

Stromal SPARC Evaluable
\((n = 125)\)
### Stromal SPARC IHC score

<table>
<thead>
<tr>
<th>SPARC level</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>71 (28)</td>
<td>185 (72)</td>
</tr>
</tbody>
</table>

- **HR high vs low (95% CI):** 1.019 (0.750–1.386)
- **P value (log rank):** 0.903

**Figure 2**

Proportion of survival over time, showing a trend towards lower survival in the low SPARC level group.
**High vs low SPARC**

<table>
<thead>
<tr>
<th></th>
<th>HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>nab-P + Gem</td>
<td>1.505 (0.978–2.315)</td>
</tr>
<tr>
<td>Gem alone</td>
<td>0.658 (0.423–1.023)</td>
</tr>
</tbody>
</table>

**Proportion of survival**

**Stratification factors, n (%)**

<table>
<thead>
<tr>
<th></th>
<th>Stromal SPARC high</th>
<th>Stromal SPARC low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nab-P + Gem n = 34</td>
<td>Gem n = 37</td>
</tr>
<tr>
<td>KPS 90–100</td>
<td>17 (50)</td>
<td>25 (68)</td>
</tr>
<tr>
<td>KPS 70–80</td>
<td>17 (50)</td>
<td>12 (32)</td>
</tr>
<tr>
<td>Liver metastasis</td>
<td>32 (94)</td>
<td>30 (81)</td>
</tr>
<tr>
<td></td>
<td>nab-P + Gem n = 97</td>
<td>Gem n = 88</td>
</tr>
<tr>
<td>KPS 90–100</td>
<td>58 (60)</td>
<td>58 (66)</td>
</tr>
<tr>
<td>KPS 70–80</td>
<td>39 (40)</td>
<td>30 (34)</td>
</tr>
<tr>
<td>Liver metastasis</td>
<td>85 (88)</td>
<td>70 (80)</td>
</tr>
</tbody>
</table>
Figure 4

A

<table>
<thead>
<tr>
<th>Protein</th>
<th>SPARC+/+</th>
<th>SPARC−/−</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPARC</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Ck-19</td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>Collagen I</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Masson</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
</tr>
<tr>
<td>α-SMA</td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
</tr>
<tr>
<td>Vimentin</td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
</tbody>
</table>

Positive pixels (%, mean ± SD)

B

Survival, %

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>SPARC+/+ (n = 15)</th>
<th>SPARC+/− (n = 12)</th>
<th>SPARC−/− (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>80</td>
<td>70</td>
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<tr>
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<td>80</td>
<td>70</td>
<td>60</td>
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<tr>
<td>30</td>
<td>70</td>
<td>60</td>
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<td>40</td>
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<td>70</td>
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<td>10</td>
</tr>
<tr>
<td>80</td>
<td>20</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

C

Paclitaxel (ng/g tumor, mean ± SEM)

<table>
<thead>
<tr>
<th>Paclitaxel (ng/g tumor)</th>
<th>SPARC+/+ (n = 7)</th>
<th>SPARC+/− (n = 11)</th>
<th>SPARC−/− (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20000</td>
<td>18000</td>
<td>16000</td>
<td>14000</td>
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<tr>
<td>40000</td>
<td>38000</td>
<td>36000</td>
<td>34000</td>
</tr>
<tr>
<td>60000</td>
<td>58000</td>
<td>56000</td>
<td>54000</td>
</tr>
</tbody>
</table>

Unpaired t test

<table>
<thead>
<tr>
<th>Unpaired t test</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPARC+/+ vs SPARC+/−</td>
<td>0.0596</td>
</tr>
<tr>
<td>SPARC+/+ vs SPARC−/−</td>
<td>0.6407</td>
</tr>
</tbody>
</table>

D

Survival, %

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>SPARC+/+</th>
<th>Control (n = 6)</th>
<th>nab-P (n = 7)</th>
<th>nab-P + Gem (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
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<tr>
<td>80</td>
<td>20</td>
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<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 1. Multivariate Analysis of OS in SPARC-Evaluable Population

<table>
<thead>
<tr>
<th>Covariatea</th>
<th>HR</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment group (nab-P + Gem vs Gem)</td>
<td>0.65</td>
<td>0.47–0.89</td>
<td>0.007</td>
</tr>
<tr>
<td>KPS (70–80 vs 90–100)</td>
<td>1.50</td>
<td>1.09–2.06</td>
<td>0.012</td>
</tr>
<tr>
<td>Presence of liver metastases (yes vs no)</td>
<td>2.12</td>
<td>1.31–3.41</td>
<td>0.002</td>
</tr>
</tbody>
</table>

a A stepwise procedure was carried out using the following factors: treatment group, age, sex, KPS, geographic region, PC primary location, presence of biliary stent, previous Whipple procedure, presence of liver metastasis, presence of pulmonary metastasis, peritoneal carcinomatosis, stage at diagnosis, number of metastatic sites, baseline level of CA 19-9, and stromal SPARC level.
Clinical Cancer Research

SPARC Expression Did Not Predict Efficacy of nab-Paclitaxel Plus Gemcitabine or Gemcitabine Alone for Metastatic Pancreatic Cancer in an Exploratory Analysis of the Phase III MPACT Trial

Manuel Hidalgo, Carlos Plaza, Monica Musteanu, et al.

Clin Cancer Res Published OnlineFirst July 13, 2015.

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