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13. SUPPLEMENTARY NOTES

14. ABSTRACT
In the first year of this three-year project, we have completed tasks following the timeline of our Statement of Work. We synthesize large amount of HMCD-SIM, enough for the entire project. We determined therapeutic efficacy of the HMCD-SIM on pancreatic cancer cell lines; and confirmed the sensitization function of the HMCD-SIM. We have established two new pancreatic cancer cell lines, and tested assay conditions for measuring GASP-1 in clinical serum samples. For mechanistic investigation, we have identified IC50 of the HMCD-SIM in combination with GEM and CDDP in BXPC-3 and MiaPaCa-2 cells. A series IHC analyses were conducted to determine the expression of OATPs on pancreatic cancer cell lines and tumor specimens. Throughout these analyses, OATP1B3 is determined to be a subject for further mutagenesis studies. These works laid a solid foundation for second year mechanistic investigation of the molecular mechanism of HMCD-SIM mediated cancer cell killing.

15. SUBJECT TERMS
Pancreatic ductal adenocarcinoma, heptamethine carbocyanine, simvastatin, conjugate, anti-tumor therapy, chemotherapeutic sensitization

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1. INTRODUCTION:

This project was based on our previous finding that a specific group of heptamethine carbocyanine dyes (HMCD) has tumor cell-specificity. When it was synthesized as chemical conjugate with simvastatin, the HMCD-SIM became a highly tumor-specific cytocidal agent. In the proposed project, HMCD-SIM will be used as an anti-tumor agent and a sensitizer in the treatment of pancreatic cancers. We hypothesized that the tumor-specific HMCD-SIM targets pancreatic cancer cells through abnormally expressed OATP channel proteins on cancer cell surface. Inside cancer cells, HMCD-SIM is localized in subcellular organelles including mitochondria, where HMCD-SIM impairs mitochondrial integrity to cause organelle leakage, and apoptotic cell death. We proposed to validate HMCD-SIM as a promising new drug for pancreatic ductal adenocarcinoma (PDAC) targeting and therapeutic sensitization; and to determine the mechanisms of HMCD-SIM-mediated cancer cell killing and therapeutic sensitization. Pancreatic cancer cells will be subjected to HMCD-SIM treatment in the presence or absence of other conventional chemotherapeutic agents to evaluate therapeutic efficacy. A series of molecular and cellular studies will be used to elucidate the mechanism of HMCD-SIM action. Xenograft tumor formation, patient derived xenograft tumor formation, and KPC transgenic pancreatic cancer models will be used to validate therapeutic efficacy of the HMCD-SIM.

2. KEY WORDS:

Pancreatic ductal adenocarcinoma, heptamethine carbocyanine, simvastatin, conjugate, anti-tumor therapy, chemotherapeutic sensitization

3. ACCOMPLISHMENTS:

What were the major goals of the project?

Aim 1: To validate HMCD-SIM as a promising new drug for PDAC targeting and therapeutic sensitization.

1.1. Determining the therapeutic efficacy of HMCD-SIM on cultured PDAC cells, human PDAC xenograft tumors, and spontaneous PDAC tumors in immune intact transgenic mice. **Partially Completed.**

1.2. Confirming the ability of HMCD-SIM to re-sensitize therapeutically resistant PDAC cell lines to chemotherapy, by obtaining reduced half maximal inhibitory concentrations (IC50) of Gemcitabine (GEM), Paclitaxel (PTX), Cisplatin (CDDP) and Tyrosine Kinase inhibitors (TKIs) in the presence of the sensitizing HMCD-SIM in representative PDAC cell lines. **Partially Completed.**

1.3. Examining sera levels of the G protein coupled receptor-associated sorting protein 1 (GASP-1) peptide in correlation with therapeutic responses of PDAC tumors and using GASP-1 peptide levels in sera to differentiate the aggressiveness of PDAC tumors in patients treated with chemotherapy, either with or without therapeutic relapse.

Aim 2: To determine the mechanisms of HMCD-SIM-mediated cancer cell kill and therapeutic sensitization.

2.1. Examining the toxic effect of HMCD-SIM conjugate on mitochondrial and lysosomal structure and function, and the corresponding loss of vitality in PDAC cell lines. **Partially Completed.**
2.2. Assessing the mechanism of HMCD-SIM-mediated sensitization. The effect of HMCD-SIM on the uptake and retention functions of other anti-tumor drugs will be investigated.
2.3. Identifying the mechanism by which HMCD-SIM-induced cholesterol loss down-regulates the Shh signaling axis to inhibit PDAC cell interaction with cells in the tumor microenvironment to reduce PDAC progression and prevent the occurrence of therapeutic resistance.

What was accomplished under these goals?

Major task 1: Determining the therapeutic efficacy of HMCD-SIM. We have synthesized and purified enough amount of HMCD-SIM conjugate for the entire study in this proposal (months 1 – 2), and we have determined efficacy of the HMCD-SIM on BXPC-3, MIA PaCa-2, UN-KPC-960 and UN-KPC-961 cell lines (months 3 – 6). The results were in good agreement with our previous finding. HMCD-SIM effectively killed these pancreatic cancer cells. IC50 values were around 5 μM after 24 hours of treatment. Mice bearing BXPC-3 and MIA PaCa-2 xenograft tumors have been tested for efficacy on inhibiting tumor formation by HMCD-SIM alone. Preliminary analysis indicated significant inhibition of tumor growth.

We have recently published a paper showing a study using the same KPC pancreatic cancer mouse model we plan to use in our project. The measurements performed in this study include fibrosis, inflammation, epithelial to mesenchymal transition and metastasis, cancer stemness and drug resistance, glucose metabolism and cytokine secretions (Edderkaoui M, et al., Gastroenterology; 2018 Dec;155(6):1985-1998). All these measurements represent key mediators of tumor growth and promotion and we plan to perform many of them in the present study. We are now in the process of generating enough breeding pairs to generate KPC mice to use for testing HMCD-SIM. We will have enough KPC mice in the next 2-4 months to start the treatment.

We have now successfully established new pancreatic cancer cell lines from surgical tumor specimens of two patients (months 7 – 18). Eight cell lines have been established from a single tumor of the first patient. Though these cell lines are mutually divergent in terms of their growth patter and cellular morphology, all have been found to have tumorigenicity as assayed with xenograft tumor formation. Cell lines from the second patient are currently been cultured continuously to passage 41. We will continue to culture these cells to 60 passages to demonstrate immortality of the cell line.

Major task 2: We have determined IC_{50} of GEM and CDDP on BXPC-3 and MIA PaCa-2 cells, individually and in combination with HMCD-SIM (months 3 – 15). Experiments are currently underway for reduced IC_{50} of GEM, PTX, CDDP, and mTOR inhibitors in combinatory treatment with HMCD-SIM (7 – 18). Control xenograft tumor formation with CS-P-2 cell lines has been completed.

Major task 3: In preparation for the current study, we have used legacy samples to optimize an ELISA method for measuring GASP-1 peptide in patient serum samples (months 1 – 12). We have

recently tested the hypothesis that GASP-1, a G protein coupled receptors (GPCRs)-associated sorting protein-1, a 156 kDa cytosolic protein, as a serum marker for human bladder cancer. This approach allows us to standardize our technology and protocol. When overexpressed in cancer cells, DASP-1 directs ligand-bound GPCRs to plasma membrane as a signal enhancer promoting cell proliferation. We collected serum samples from 13 healthy donors as control and 30 bladder cancer patients with IRB approval. Serum GASP-1 was assessed by ELISA (Proplex Technologies, Dresher, PA). Data were analyzed with Graph-pad prism 6.0 for statistical clinical correlation. GASP-1 protein was also measured in 8 cultured bladder cancer cell lines with or without GEM treatment by western blot and 12 archived cancerous and 5 normal bladder tissues by immunohistochemistry. Our results reveal that higher serum GASP-1 expression was found in bladder cancer patients compared to controls ($p<0.001$). The area under the ROC curve (AUC) for GASP-1 to discriminate bladder cancer from normal was 0.8096 (95% confidence interval [CI], 0.7202 to 0.899; $P<0.0001$). GASP1 expression in stage-Ta, -T1 and -TIS and PUNLMP, low- and high-grade were all higher than controls statistically (all $p<0.05$). GASP-1 was detected in clinical bladder cancer tissue specimens and cultured bladder cancer cell lines. At tissue level, semi-quantitative IHC expression of cytoplasmic GASP-1 was comparable in normal and cancerous bladder epithelial cells but nuclear membrane GASP-1 expression in the cancer group was significantly higher than control ($p=0.0036$).The nuclear membrane level of GASP-1 was also higher in metastatic and GEM-treated bladder cancer cells. This method will be used for this DoD study using serum samples collected from pancreatic cancer patients, in comparison to specimens collected from normal controls and from patients with confirmed pancreatitis.

We have now obtained the first 40 plasma samples of pancreatic cancer patients. GASP-1 ELISA of these samples will be performed in the coming month. We are also collecting more patient plasma from clinical pancreatic cancer patients.

Major task 4: We have documented impaired mitochondrial function using three methods: 1) Immunohistochemical staining for cytochrome C release from mitochondria to cytosol following HMCD-SIM treatment; 2) Quantitative flow cytometry for reduced mitochondrial membrane potential with HMCD-SIM-treated cancer cells whose mitochondria were pre-loaded with either rhodamine 123 or JC1 (months 1 – 6).

Major task 5: We are currently locating an isolated cell culture incubator for culture cells with radioactive gemcitabine-^{13}C-$^{15}N2$ (months 1 – 6). For mutagenesis studies, we decided to obtain a human full length OATP1B3 cDNA clone from commercial sources (months 13 - 18).

Major task 6: We have confirmed that HMCD-SIM inhibits cholesterol level significantly in treated cancer cells, with more prominent effect on cholesterol level of the mitochondria (months 1 - 6).

What opportunities for training and professional development has the project provided?

The project provided training for postdoctoral fellows Lijuan Yin, Liyuan Yin, and Ji Lyu, in a novel area in pancreatic research with Dr. Chung, an expert in cancer biology and metastasis.

These fellows also worked with Drs. Pandol and Tomlinson who are experts in clinical pancreatic cancer research and treatment.

What do you plan to do during the next reporting period to accomplish the goals?

In the next reporting period, we will keep close observation to the timeline of our Statement of Work. Once our HRPO and ACURO protocols are approved, we will start immediately to conduct xenograft tumor formation and test patient derived xenograft formation.

4. IMPACT:

What was the impact on the development of the principal discipline(s) of the project?

In the first year of this three-year project, we have completed tasks following the timeline of our Statement of Work. These works laid a solid foundation for second year mechanistic investigation of the molecular mechanism of HMCD-SIM mediated pancreatic cancer cell killing.

What was the impact on other disciplines?

In our first-year studies, HMCD-SIM is determined to be able to kill pancreatic cancer cells. These results will encourage us to test HMCD-SIM to kill other human cancer cells.

What was the impact on technology transfer?

Nothing to report.

What was the impact on society beyond science and technology?

Nothing to report.

5. CHANGES/PROBLEMS:

Changes in approach and reasons for change

Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that had a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use of biohazards and/or select agents

Nothing to report.

6. PRODUCTS:

Publications, conference papers, and presentations

Journal publications

Nothing to report

Books or other non-periodical, one-time publications.

Nothing to report

Other publications, conference papers and presentations.

Development of agents targeting membrane cholesterol and mitochondria to accelerate pancreatic cancer cell kill. Accelerating the pipeline for improving pancreatic cancer, Translational Symposium, Digestive Disease Week (DDW) 2019, San Diego Convention Center, 33ABC, May 18. 2019

Website(s) or other Internet site(s)

Nothing to report.

Technologies or techniques

Nothing to report.

Inventions, patent applications, and /or licenses

Nothing to report.

Other products

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

What individuals have worked on the project?

Leland W. K. Chung (Initiating PI)	Experimental design	6 months
Yi Zhang	HMCD-SIM synthesis and purification	2 months
Chia-Yi Chu	Cell culture and cytotoxicity testing	2 months
Ruoxiang Wang	Culture of patient samples	4 months
Haiyen E. Zhau	GASP-1 ELISA development and evaluation	2 months
Stephen Pandol (Partnering PI)	Patient recruitment and protocol preparation	2 months
Edderkaoui Mouad	Animal breeding	3 months
Nicholas Nissen	Patient recruitment	6 months
Andrew Hendifar	Patient recruitment	2 months
James Tomlinson	Patient recruitment and protocol preparation	2 months
Michael Lewis	GASP-1 biomarker evaluation	2 months

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report.

What other organizations were involved as partners?

Nothing to report.

8. SPECIAL REPORTING REQUIREMENTS:

COLLABORATIVE AWARDS:

QUAD CHARTS:

9. APPENDICES: