

AWARD NUMBER: W81XWH-16-1-0699

TITLE: Furanyl Fatty Acid Inhibition of FABP5 as a Mechanism for Treatment and Prevention of Cancer

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REPORT DATE: NOVEMBER 2018

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;
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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE NOVEMBER 2018		2. REPORT TYPE Annual Technical		3. DATES COVERED 30 Sep 2017 - 29 Sep 2018	
4. TITLE AND SUBTITLE Furanyl Fatty Acid Inhibition of FABP5 as a Mechanism for Treatment and Prevention of Cancer				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER W81XWH-16-1-0699	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Gregory Tochtrop E-Mail: gpt6@case.edu				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Case Western Reserve University 10900 EUCLID AVE CLEVELAND OH 44106-1712				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT : We propose that inhibition of FABP5 represents a novel approach to diverting endogenous RA from pro-proliferative (PPAR δ) to anti-proliferative (RAR) receptors, and further propose the use of furan-containing fatty acids as agents to target RA to RAR. We hypothesize that this pharmacologic inhibition will prevent the oncogenic effects of FABP5 overexpression in highly relevant breast cancer models that display a high ratio of FABP5:CRABP-II expression.					
15. SUBJECT TERMS NONE LISTED					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Unclassified	18. NUMBER OF PAGES 9	19a. NAME OF RESPONSIBLE PERSON USAMRMC
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code)

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Introduction:

Retinoic acid (RA) is a potent anticarcinogenic agent that functions by regulating the expression of multiple genes through its ability to activate two nuclear receptors: RA receptors (RAR) and the peroxisome proliferator-activated receptor δ (PPAR δ). However, RA's utility as a therapeutic agent is limited by RA resistance that is acquired in some tumors, and the paradoxical observation that in some tumors RA actually potentiates tumor growth. Activation of RAR results in inhibition of cancer cell growth, while activation of PPAR δ leads to enhanced growth and survival. The key to regulating the partitioning of RA between these two opposing pathways lies in the two proteins that deliver RA to their respective transcription factors: cellular Retinoic acid binding protein 2 (CRABP2), which targets the hormone to RAR, and fatty acid binding protein 5 (FABP5), which transports it to PPAR δ . Hence, cells that express a high level of FABP5 become resistant to RA-induced growth inhibition, and instead, display enhanced proliferation in response to RA being targeted to PPAR δ . Recently, our laboratories have identified a class of furan-containing fatty acids (FAs) as a novel class of naturally occurring, dietarily available, high-affinity inhibitors of FABP5. Based on our RA signaling model we predict that by blocking FABP5, furanyl-FAs will specifically divert RA to RAR and consequently will overcome RA-resistance and suppress the growth of FABP5-overexpressing tumors. The goal of this work is to further investigate this partitioning between RAR and PPAR δ , investigate the metabolic fate of furanyl-FAs, and determine if these molecules can serve as effective chemopreventive agents.

Major Goals:

Specific Aim 1. Define the ability of furanyl-FAs to perturb the CRABP2/FABP5 signaling balance.

- 1.1. Define a structure-activity relationship for naturally occurring furanyl-FAs.
- 1.2. Examine the ability of high affinity FABP5-binding furanyl-FAs to target RA to the CRABP2/RAR path.
- 1.3. Determine the ability of furanyl-FAs to inhibit the growth of cultured carcinoma cells.

Specific Aim 2. Define the metabolic fate(s) of furanyl-fatty acids.

- 2.1. Develop a comprehensive understanding of the metabolic and catabolic fate(s) of furanyl-FAs using a mass isotopomer approach in perfused organ systems.
- 2.2. Examine the rate(s) of metabolism/catabolism in normal tissues, and cancer cell lines.

Specific Aim 3. Assess the effects of furanyl-FAs on mammary tumor development *in vivo*.

- 3.1. Assess the efficacy of furanyl-FAs in inhibiting tumor development in xenograft mouse models of breast cancer.
- 3.2. Test the ability of furanyl-FAs to prevent tumor formation in the transgenic MMTV-Neu/Erb-B2 model of mammary carcinogenesis.

This report detailed the activities achieved in both Levi and Tochtrop lab.

Specific Aim 1. Define the ability of furanyl-FAs to perturb the CRABP2/FABP5 signaling balance.

1.1 Define a structure-activity relationship for naturally occurring furanyl-FAs.

These activities have been completed as was detailed in the previous report.

1.2 Examine the ability of high affinity FABP5-binding furanyl-FAs to target RA to the CRABP2/RAR path.

Several furanyl-FAs and other FA-like compounds (Fig. 1) were tested so far. Data established with the compound N-arachidonoylaminophenol is presented in this report as an example for analyses done with compounds that serve the two FABP5-inhibitor criteria. Transcriptional activation assays used to test the effect of compounds on activation of PPAR δ (Fig. 2A), were performed for all compounds showing high binding affinity toward FABP5. Compounds were further tested for their ability to channel endogenous RA towards CRABP2/RAR path by measuring expression levels of RAR and PPAR δ target genes (Fig. 2B, 2C). The triple-negative breast cancer line MDA-MB-231 and the mammary carcinoma cell line NaF were utilized for these

assays. In addition to the target genes suggested in the proposal other target genes were tested including RAR target genes ADRRC3, CCND1 and CAS9 and PPAR δ targets CD47, MMP9 and MMP2.

1.3 Determine the ability of furanyl-FAs to inhibit the growth of cultured carcinoma cells.

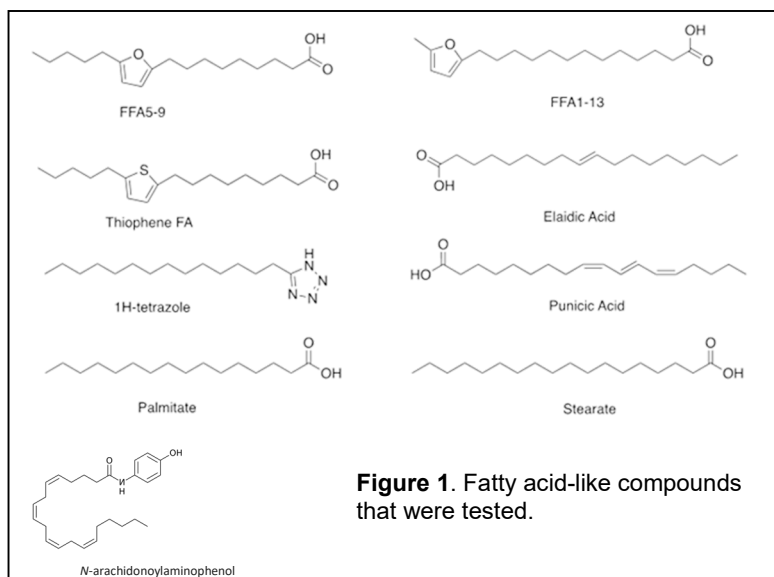


Figure 1. Fatty acid-like compounds that were tested.

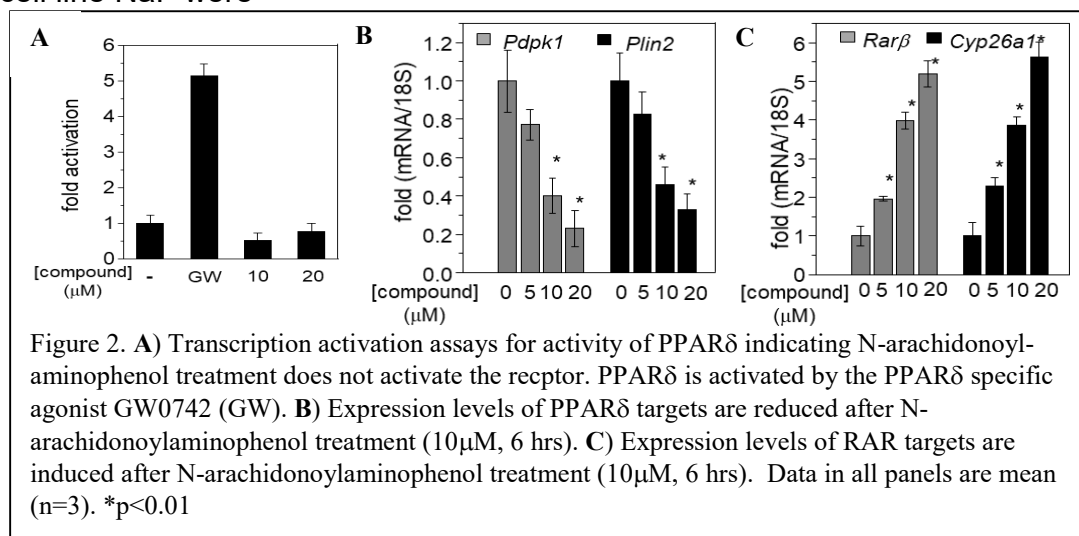
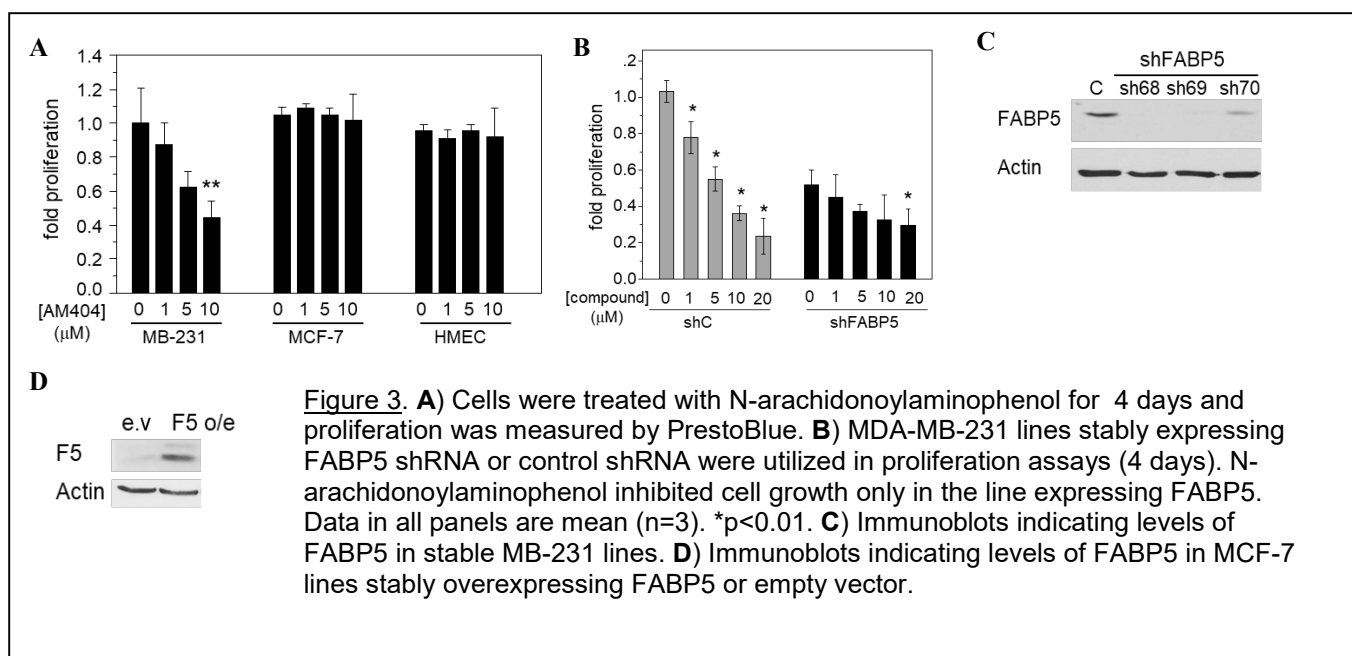


Figure 2. A) Transcription activation assays for activity of PPAR δ indicating N-arachidonoylaminophenol treatment does not activate the receptor. PPAR δ is activated by the PPAR δ specific agonist GW0742 (GW). B) Expression levels of PPAR δ targets are reduced after N-arachidonoylaminophenol treatment (10 μ M, 6 hrs). C) Expression levels of RAR targets are induced after N-arachidonoylaminophenol treatment (10 μ M, 6 hrs). Data in all panels are mean (n=3). *p<0.01

Several compounds that serve the criteria for FABP5 inhibitors were further utilized in proliferation assays. MDA-MB-231 and NaF cells were utilized as models for carcinoma cell that highly expresses FABP5 while the breast carcinoma line MCF-7 and the normal mammary epithelial cells HMEC was used as a model for cell in which FABP5 expression is low (Fig. 3A). In addition, three stable 231 lines were established that stably overexpress FABP5 shRNA or control shRNA (Fig. 3C), and two MCF-7 lines that stably overexpresses human FABP5 or empty vector (Fig. 4D). These lines are used to validate the effect of tested compound on cells is mediated by FABP5 (Fig. 3B).



Specific Aim 2. Define the metabolic fate(s) of furanyl-fatty acids.

2.1. *Develop a comprehensive understanding of the metabolic and catabolic fate(s) of furanyl-FAs using a mass isotopomer approach in perfused organ systems.*

These activities have been completed as was detailed in the previous report.

2.2. *Examine the rate(s) of metabolism/catabolism in normal tissues, and cancer cell lines.*

Specific Aim 3. Assess the effects of furanyl-FAs on mammary tumor development in vivo.
IACUC approval for mice protocol was established.

3.1. *Assess the efficacy of furanyl-FAs in inhibiting tumor development in xenograft mouse models of breast cancer.*

Nothing to report

3.2. *Test the ability of furanyl-FAs to prevent tumor formation in the transgenic MMTV-Neu/Erb-B2 model of mammary carcinogenesis.*

Nothing to Report

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

- Levi attended AACR meeting "Obesity and Cancer: Mechanisms Underlying Etiology and Outcomes", 2018.
- Levi and Stewart attended The 2018 4th International FASEB Conference on Retinoids. Levi attended career development workshop at this meeting.
- Two undergraduate students were working on this project during the summer in the Levi lab. Students were training in cancer research under Levi and Stewart supervision.

How were the results disseminated to communities of interest?

- Levi presented a poster at the Obesity and Cancer: Mechanisms Underlying Etiology and Outcomes.
- Stewart presented poster at the 2018 retreat of Case Comprehensive Cancer Center.
- Stewart gave a talk and presented a poster at the 2018 4th International FASEB Conference on Retinoids.

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

We currently have few molecules that were validated by cell culture assays to inhibit FABP5 and shift RA signaling. We plan to further validate the specificity of the compounds to FABP5 by testing the effect of the compounds on stable cell lines (mentioned above) in which levels of FABP5 are manipulated. In addition, binding affinity to other FABP5 will be measured. Next, we aim in moving forward to Aim 2 and Aim 3.

IMPACT:

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

We were able to demonstrate that indeed, our criteria for screening for FABP inhibitor are appropriate. Most important, we were able to demonstrate the dual activity of FABP5 inhibitor that not inhibits transcriptional activity of PPAR δ but also shifts RA to activate RAR. We demonstrate that targeting FABP5 inhibit growth of cancer cells in culture.

We have developed methods to efficiently gain access to the complement of furan-containing fatty acids using chemical synthesis. This will allow scalability not possible through isolation from natural sources. Further, we have been able to show that these molecules will undergo beta oxidation, but that rate is greatly attenuated compared to standard fatty acids.

What was the impact on other disciplines?

As FABP5 is highly expressed in many types of cancer, this approach for treatment and prevention of tumors can be useful for other cancers as well.

We predict that the results we describe here will be important for the fields of organic synthesis and metabolism. In terms of synthesis, orthogonal alkylation of furan is important, and could be widely used. In terms of metabolism, it is generally not known what the fate of furan is in mammalian systems.

What was the impact on technology transfer?

Nothing to Report.

What was the impact on society beyond science and technology?

Nothing to Report.

CHANGES/PROBLEMS:

Changes in approach and reasons for change

We expanded the scope of fatty acids to consider in the role of cancer chemopreventive agents. This proposal was based on our strong preliminary data on furan-containing fatty acids, but meanwhile we also tested other common dietary fatty acids. For example, we have been able to show that palmitate and stearate displays similar effects as compared to F_a.

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.

PRODUCTS:

Publications, conference papers, and presentations

Nothing to Report.

Report only the major publication(s) resulting from the work under this award.

Nothing to Report.

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.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name: Gregory Tochtrop

Project Role: PI/Professor

Researcher Identifier (e.g. ORCID ID): <https://orcid.org/0000-0003-2447-254X>

Nearest person month worked: 3

Contribution to Project: Project oversight, and direct supervision of Ms. Stewart, Dr. Han, Ms. Shang, and completion of the metabolomics work reported here.

Name: Liraz Levi

Project Role: PI/Instructor/Research Scientist

Researcher Identifier (e.g. ORCID ID): <https://orcid.org/0000-0001-7462-2396>

Nearest person month worked: 12

Contribution to Project: Project oversight, direct supervision of Ms. Stewart, establishing stable cell lines, biochemical molecular and cells assays (Aim 1), data analysis.

Name: Elizabeth Stewart

Project Role: Graduate Student

Researcher Identifier (e.g. ORCID ID): N/A

Nearest person month worked: 12

Contribution to Project: Contributions to small molecule synthesis, and biological contributions to Aim 1.

Name: Grace Shang

Project Role: Research Assistant

Researcher Identifier (e.g. ORCID ID): N/A

Nearest person month worked: 12

Contribution to Project: Small molecule synthesis.

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