Plasma cell-free DNA methylation: a liquid biomarker of hepatic fibrosis

We recently reported dynamic epigenetic markers of fibrosis detectable in patients’ plasma that may have utility in non-invasive diagnosis and staging of fibrosis in patients with chronic liver disease. Specifically, we uncovered DNA methylation markers at the human PPARγ promoter detectable in circulating cell-free DNA (ccfDNA) that display differential methylation densities. Remarkably, PPARγ hypermethylation correlated with progression to cirrhosis in alcoholic liver disease (ALD) and with specific stages of liver fibrosis in non-alcoholic fatty liver disease (NAFLD). Furthermore, ccfDNA signatures were traced back to the molecular pathology in fibrotic liver tissue, providing a biomarker of the underlying pathological process and defining hepatocytes as the source of hypermethylated DNA found in plasma.

The original study posed several important outstanding questions: (1) Can ccfDNA methylation be used as a biomarker of fibrosis in liver diseases of other aetiologies? (2) Does the presence of hepatocellular carcinoma (HCC) alter the biomarker in plasma? (3) Does presence of fibrosis in other organs generate similar biomarker profiles?

In the present letter, we answer these questions and demonstrate the broader utility of DNA methylation at three CpG dinucleotides within PPARγ promoter in several new patient cohorts (figure 1A and table 1). Employing pyrosequencing we detect hypermethylation at all three CpGs in ccfDNA from a cohort of patients suffering from cirrhosis caused by chronic HBV infection (figure 1B–D). The level of hypermethylation resembled that found in patients with cirrhotic NAFLD and ALD in
our original study. However, since the HBV cohort was of another ethnicity to our original UK-based patients with NAFLD and ALD, we also measured methylation density in a Turkish NAFLD cohort, which was mirroring those detected in the HBV cohort. Our new data also demonstrate that presence of HCC with chronic liver disease does not alter the specificity of the DNA methylation markers for detection of liver fibrosis (figure 1B–D). As we had access to explant liver tissue from patients with NAFLD, HBV and HCC, we determined methylation densities in the liver (figure 1E–G). A high similarity was observed between the degree of DNA methylation at PPARγ gene promoter in ccfDNA and in the patient-matched liver tissues. We found a significant spread of values for DNA methylation in the healthy control ccfDNA, this being in contrast with our original UK-based study in which low-level methylation density was consistent across individuals within the control.

Table 1  Characteristics of patient cohorts used in the study

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Gender (male/female)</th>
<th>BMI (kg/m²)</th>
<th>Diabetes (%)</th>
<th>ALT (IU/L)</th>
<th>AST (IU/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAFLD cohort</td>
<td>56 ± 7</td>
<td>10/3</td>
<td>29.8 ± 3.2</td>
<td>69</td>
<td>33 ± 23</td>
<td>54 ± 36</td>
</tr>
<tr>
<td>Hepatitis B cohort</td>
<td>51 ± 7</td>
<td>10/3</td>
<td>26.5 ± 2.4</td>
<td>38</td>
<td>47 ± 50</td>
<td>80 ± 64</td>
</tr>
<tr>
<td>HCC cohort</td>
<td>57 ± 7</td>
<td>16/1</td>
<td>27.5 ± 4.2</td>
<td>29</td>
<td>55 ± 36</td>
<td>65 ± 53</td>
</tr>
</tbody>
</table>

Systemic sclerosis cohort (n=30)

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Gender (male/female)</th>
<th>BMI (kg/m²)</th>
<th>Disease duration (years)</th>
<th>Heart involvement (%)</th>
<th>Lung involvement (%)</th>
<th>DLCO (%)</th>
<th>Antinuclear antibody-positive (%)</th>
<th>Anticentromere antibody-positive (%)</th>
<th>Antitopoisomerase I antibody-positive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse cutaneous limited SSc</td>
<td>55±14</td>
<td>10/20</td>
<td>26±3.8</td>
<td>12 (40%)</td>
<td>7.5±4 (7%)</td>
<td>11 (37%)</td>
<td>71.7±17 (30 (100%))</td>
<td>11 (37%)</td>
<td>12 (40%)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Viral hepatitis in HCC cohort: HBV-positive, n=8; HCV-negative, n=2; HBV-positive and HCV-positive, n=3.

Data expressed as mean±SD or median (range).

BMI, body mass index; HCC, hepatocellular carcinoma; NAFLD, non-alcoholic fatty liver disease; SSc, systemic sclerosis.
group. We are unable to explain this wider spread of methylation densities in the Turkish cohort, but cannot rule out an undetected liver disease in the apparently ‘healthy’ controls that display elevated ccfDNA methylation.

We next determined if hypermethylation is specific to fibrosis of liver origin. To this end, we quantified ccfDNA methylation in a cohort of patients with limited and diffuse systemic sclerosis (SSc) who have various combinations of skin, lung and kidney fibrosis, but no hepatic fibrosis. All three CpG sites in SSc were relatively hypomethylated (figure 1B–D), with similar methylation densities between individual patients with SSc. All methods relating to the study are listed in ‘online supplementary materials and methods 1’.

This important validation study supports our original hypothesis that hypermethylation at the PPARγ gene promoter is a marker for fibrotic progression of chronic liver disease and holds true for viral, alcoholic and metabolic disease aetologies. As fibrosis in other organs does not generate a similar epigenetic signature, it is likely that the PPARγ hypermethylation specifically reflects a liver pathology. The ability to detect and quantify hypermethylation at the promoter of the PPARγ in ccfDNA as a new liquid biomarker that specifically reports the fibrotic progression of liver diseases of multiple aetiologies offers the potential for a cost-effective blood-based liquid biomarker of liver fibrosis.

Buket Yiğit, Marie Boyle, Oğuz Özler, Nihan Erden, Faik Tutucu, Timothy Hardy, Christina Bergmann, Joerg H W Distler, Gupse Adalı, Murat Dayanagç, Derek A Mann, Mujdat Zeybel, Jelena Mann

1Department of Gastroenterology and Hepatology, School of Medicine, Koç University, Istanbul, Turkey
2Faculty of Medical Sciences, Institute of Cellular Medicine, Newcastle University, Newcastle upon Tyne, UK
3Department of Internal Medicine, University of Erlangen-Nuremberg, Erlangen, Germany
4Liver Transplantation Unit, Istanbul Bilim University, Florence Nightingale Hospital, Istanbul, Turkey

Correspondence to Dr Jelena Mann, Institute of Cellular Medicine, Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, NE2 4HH, UK; jelena.mann@ncl.ac.uk

Acknowledgements The authors gratefully acknowledge use of the services and facilities of the Koç University Research Center for Translational Medicine (KUTTAM), equally funded by the Republic of Turkey Ministry of Development Research Infrastructure Support Program. Findings, opinions or points of view expressed on this article do not necessarily represent the official position or policies of the Ministry of Development.

Contributors BY: acquisition, analysis and interpretation of majority of the data for the manuscript. MB, OO, CB, NE, FT, TH, GA, MD, JHWD: acquisition of sample or data for the manuscript. MZ: acquisition, analysis and interpretation of data for the manuscript; drafting the manuscript and revising it critically for important intellectual content. JM, DAM: conception and design of the manuscript, acquisition of data for the manuscript, drafting the manuscript and revising it critically for important intellectual content.

Funding Marie Curie Fellowship, European Commission and TUBITAK 2232 Fellowship, National Institute on Alcohol Abuse and Alcoholism (AA018663), and Medical Research Council (MR/K001949/1, MR/L002094/1).

Competing interests None declared.

Ethics approval Koç University Ethics Committee for Clinical Research, 04.02.2016-2016.024.1RB2.005, 18.9.2015-2015.215.1RB1.020.

Provenance and peer review Not commissioned; internally peer reviewed.

Open access This is an open access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2018. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

Open access article. To view the supplementary materials online, please visit the journal website (http://dx.doi.org/10.1136/gutjnl-2017-315668).

MZ and JM contributed equally.

Received 14 November 2017
Revised 24 November 2017
Accepted 30 November 2017
Published Online First 20 January 2018

doi:10.1136/gutjnl-2017-315668

REFERENCES