A B-Bio Algebraic-Geometric Framework for Interpretable Hepatitis and Liver Cancer Progression Modeling : Disease as Directed Curvature Accumulation and Entropy Production

Abhishek Bansal
Founder & Principal Consultant, New Era Consultancy Services, India

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Background:

Chronic hepatitis and liver cancer form a continuous spectrum driven by persistent inflammation, tissue remodeling, and progressive loss of physiological organization. Conventional staging and black-box models miss cumulative damage, irreversibility, and malignant transition because they treat the continuum as disconnected snapshots.

Objectives:

To reframe liver disease as a process of continuous state evolution rather than disconnected clinical stages; to distinguish the hidden biological state from its projected observables, including biomarkers, imaging, and physiological signals; and to provide a deterministic, interpretable model linking metabolism, transport, inflammation, repair, and malignancy. The framework is intended to support multimodal integration, longitudinal monitoring, therapy-response interpretation, and recurrence-versus-regeneration differentiation.

Methods:

Proposed Novel B-Bio Theory, Frameworks and Pillars on BVidAL Clinical Software Suite

- **Represents liver disease as a continuous state trajectory evolving via directed curvature accumulation and entropy production**
- **Defines liver state on a unified stratified algebraic manifold integrating structure, transport, metabolism, inflammation, and malignancy**
- **Models clinical data (ALT, AST, imaging, signals) as projections of a hidden evolving biological state**
- **Encodes progression using:**
  - **Curvature → structural deformation**
  - **Entropy → irreversibility**
  - **Operators → therapy, inflammation, repair**
  - **Transport → flow and metabolic coupling**
- **Makes disease progression:**
  - **Deterministic**
  - **Interpretable**
  - **Mechanistically grounded (not black-box)**

11 pillars of Novel Bansal-Biology Theory

- **Algebra**: stratified liver-state organization
- **Manifold**: healthy and diseased hepatic state space
- **Projection**: biomarkers/imaging as observable shadows
- **Trajectory**: disease as continuous evolution
- **Curvature**: structural deformation across stages
- **Operators**: inflammation, therapy, inhibition, repair
- **Entropy**: irreversibility of progression
- **Holonomy**: path dependence in advanced disease
- **Fiber Bundle**: hidden state over clinical context
- **Tensor**: fibrosis, flow, and remodeling coupling
- **Connection/Transport**: blood, metabolism, membrane exchange

Results/Outcomes:

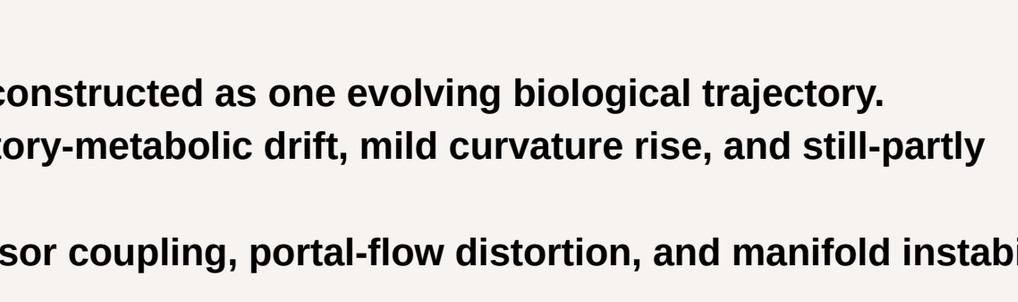
- **Continuum model: NAFLD → fibrosis → cirrhosis → HCC is reconstructed as one evolving biological trajectory.**
- **Early-stage reading: chronic hepatitis/NAFLD shows inflammatory-metabolic drift, mild curvature rise, and still-partly recoverable transport coherence.**
- **Fibrosis and cirrhosis: distributed curvature accumulation, tensor coupling, portal-flow distortion, and manifold instability become dominant.**
- **Malignant transition: HCC appears as localized high-curvature divergence with unstable boundaries, holonomy/path dependence, and entropy saturation.**
- **Multimodal outcome: imaging, biomarkers, and physiological signals remain linked as projections of one hidden liver state.**

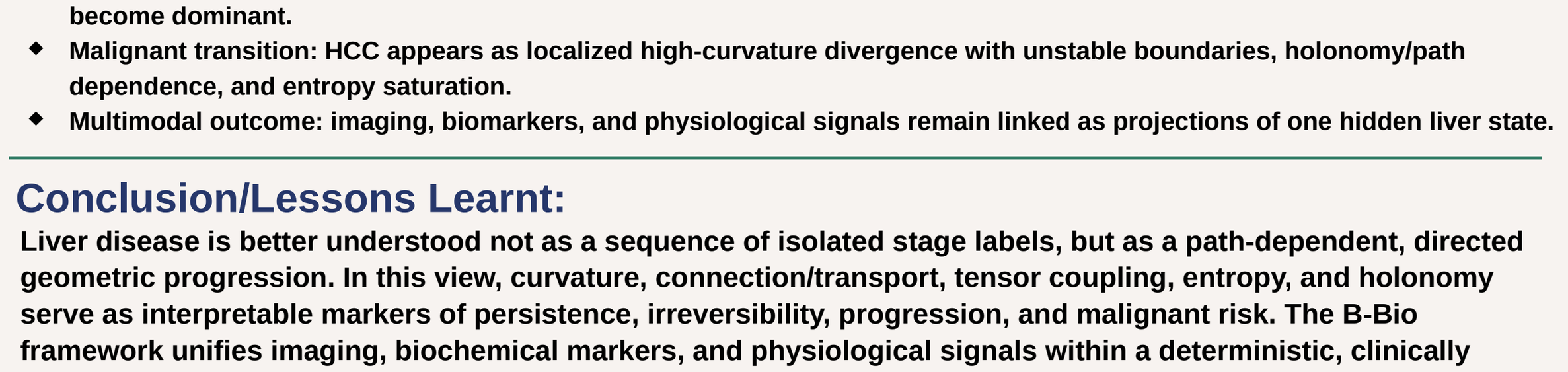
Conclusion/Lessons Learnt:

Liver disease is better understood not as a sequence of isolated stage labels, but as a path-dependent, directed geometric progression. In this view, curvature, connection/transport, tensor coupling, entropy, and holonomy serve as interpretable markers of persistence, irreversibility, progression, and malignant risk. The B-Bio framework unifies imaging, biochemical markers, and physiological signals within a deterministic, clinically interpretable state-space, enabling longitudinal, multimodal, non-black-box clinical reasoning, including recurrence-versus-regeneration distinction and therapy interpretation as operator-driven trajectory modification.

Case implications :

- Portal hypertension reflects flow-geometry instability
- Recurrence vs regeneration needs trajectory history
- Therapy can redirect, stabilize, or destabilize progression.





Stable manifold -> curvature perturbation -> fibrotic remodeling -> manifold instability -> tumor formation

Curvature	Entropy	Operators	Projection
Tracks structural deformation across disease stages	Captures irreversibility and direction of progression	Encode inflammation, therapy, inhibition, and repair	Links biomarkers, imaging, and signals to one evolving state

Contact information

Email: abhishekbansaL006@gmail.com
ORCID: 0000-0002-2572-9004
https://ieee-dataport.org/authors/abhishek-bansal

New Era Consultancy Services