Optimal Image-Based Biomarkers for Prediction of Incisional Hernia Formation

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Disclosures

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All photos are Dr. Fischer’s patients, and each patient has provided permission for use of photos and videos.
Incisional hernia (IH) is a morbid surgical disease

↑ Pain
↓ Function
↓ Well-being
↓ Appearance


Incisional hernia is prevalent

~1.7M
Open abdominal surgeries every year

~99,000
IH repairs every year

~$7.3B
Annual IH-related cost burden


Risk prediction to identify targets


Current risk prediction models are limited
Unstructured data may be critical for improving risk prediction.

- **~20% STRUCTURED**
  - Demographic data
  - ICD/CPT codes
  - Lab results

- **~80% UNSTRUCTURED**
  - e.g. Imaging, clinical documentation
Preoperative Computed Tomography Morphological Features Associated with Hernia Formation

Matched-pair case-control study  100 matched patients analyzed  Morpphologic features

<table>
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<th>Structural widening of the rectus complex</th>
<th>Larger intra-abdominal volume</th>
<th>Abdominopelvic skeletal musculature atrophy</th>
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<td>↑ linea alba and rectus muscle width</td>
<td>↓ fat, abdominopelvic, and total pelvic volume</td>
<td>↓ abdominopelvic muscle tissue and pelvic body wall volume</td>
</tr>
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</table>

Fischer, McAuliffe, Torigian et al.

Visual Abstract by @thowMD

#AmerSurg22
Optimal Biomarker (OBM) Method

Identifying **synergistic** features may improve accuracy

Selection of least redundant, most powerful risk predictors

- Biomarkers
- Multi-modal risk prediction
- IH Prevention

**Our completed work**

Structured data → Unstructured data

Image Processing → Discriminative Features

OBM method

Domains of risk

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**Preoperative Computed Tomography Morphological Features Associated with Hernia Formation**

- Matched-pair case-control study
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Fischer, McAuliffe, Torigian et al. [AmerSurg22]
Objectives

Identify optimal biomarkers (OBMs) from preoperative CT imaging which are most predictive of IH development.

Employ multiple machine learning (ML) algorithms using these OBMs to compare predictive performance.
Cohort selection

Colorectal surgery patients 2005-2019 (n = 21,501)

Patients meeting inclusion criteria (n = 9,685)

Matched patients (n = 830)

Matched population (n = 212)

• Matched 1:1 for development of IH
• Matched on 10 criteria:
  ▪ Age
  ▪ Sex
  ▪ Race
  ▪ Ethnicity
  ▪ Smoking
  ▪ Diabetes mellitus
  ▪ Pre-index ventral incisional hernia repair
  ▪ Pre-index abdominal surgery
  ▪ Index laparoscopic surgery
  ▪ Index open surgery
279 volumetric, linear, textural, and intensity features extracted from each CT
<table>
<thead>
<tr>
<th>Top 6 OBMs</th>
<th>No hernia [Mean (SD)]</th>
<th>Hernia [Mean (SD)]</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AbdPlvs VAT vol normalized (m$^3$)</td>
<td>0.06 (0.04)</td>
<td>0.08 (0.04)</td>
<td>0.02</td>
</tr>
<tr>
<td>AbdPlvs IAM vol normalized (m$^3$)</td>
<td>0.18 (0.05)</td>
<td>0.19 (0.05)</td>
<td>0.03</td>
</tr>
<tr>
<td>Plvs VAT vol normalized (m$^3$)</td>
<td>0.11 (0.06)</td>
<td>0.13 (0.07)</td>
<td>0.01</td>
</tr>
<tr>
<td>AbdPlvs IAM/OAM</td>
<td>0.46 (0.05)</td>
<td>0.48 (0.06)</td>
<td>0.02</td>
</tr>
<tr>
<td>Plvs VAT/OAM</td>
<td>0.12 (0.06)</td>
<td>0.14 (0.06)</td>
<td>0.02</td>
</tr>
<tr>
<td>Plvs IAM vol normalized (m$^3$)</td>
<td>0.29 (0.08)</td>
<td>0.32 (0.08)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Abd = abdomen  
Pivs = pelvis  
AbdPlvs = abdomen-pelvis  
VAT = visceral adipose tissue  
IAM = inner aspect of body wall skeletal musculature  
OAM = outer aspect of body wall skeletal musculature  
Vol = volume  
Normalized = normalized to body region height  
SD = standard deviation
Pathophysiology of IH

RISK

Increased intra-abdominal volume/pressure

EXPOSURE

Abdominal surgery

OUTCOME

Failed fascial healing
Incisional Hernia
<table>
<thead>
<tr>
<th>The number of features in best subsets</th>
<th>Index of features in best subsets</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>0.69</td>
<td>0.62</td>
<td>0.76</td>
<td>0.79</td>
</tr>
<tr>
<td>2</td>
<td>19,107</td>
<td>0.81</td>
<td>0.81</td>
<td>0.81</td>
<td>0.85</td>
</tr>
<tr>
<td>3</td>
<td>109,19,120</td>
<td>0.83</td>
<td>0.86</td>
<td>0.81</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>109,19,107,120</td>
<td>0.83</td>
<td>0.86</td>
<td>0.81</td>
<td>0.84</td>
</tr>
<tr>
<td>5</td>
<td>109,19,107,112,120</td>
<td>0.81</td>
<td>0.81</td>
<td>0.81</td>
<td>0.82</td>
</tr>
<tr>
<td>6</td>
<td>109,19,107,112,120,13</td>
<td>0.67</td>
<td>0.71</td>
<td>0.62</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Feature 19 – AbdPelvis IAM volume norm
Feature 107 - Pelvis VAT volume norm
Feature 109 - AbdPelvis VAT volume norm
Feature 120 - Pelvis VAT/OAM volume ratio
Feature 112 - AbdPelvis IAM/OAM volume ratio
Feature 13 - Pelvis IAM volume norm
Better than existing models relying on structured data (AUC = 0.82)
Conclusions

• *Increased intra-abdominopelvic volume/pressure* is the salient pathophysiologic driver and mechanism for IH formation

• ML models using OBMs are *highly predictive* for IH development

• Next generation of prediction will maximize *unstructured data* through techniques in AI
Next steps: multi-modal IH risk prediction

Our completed work

Structured data

Unstructured data

Image Processing

Discriminative Features

OBM method

Biomarkers

Incorporate structured and unstructured data into one powerful risk model

Multi-modal risk prediction

IH Prevention

- Structured data
- Image-based features
- Text-based features
The Data Lake
The Data Lake
The Data Lake
Methods in Artificial Intelligence

- Understanding
  - Audio Processing (Systems recognizing and creating speech and audio)
  - Natural Language Processing (Systems comprehending human language)
  - Vision (Systems processing and interpreting images)

- Learning
  - Machine Learning (Systems learning from experience/data)
Generative AI

Foundation Models
My surgical dressing is soaked in blood. What should I do?

If your surgical dressing is soaked in blood, it’s important to contact your healthcare provider or surgeon as soon as possible. This could be a sign of bleeding or other complications related to the surgical site. Your healthcare provider will be able to evaluate the situation and determine the best course of action, which may include adjusting the dressing, prescribing medications, or scheduling additional tests or procedures. Until you are able to see your healthcare provider, it’s important to keep the surgical site elevated and apply direct pressure to the area to help stop the bleeding. If you experience any additional symptoms such as dizziness, weakness, or chest pain, seek medical attention immediately.