Predicting Patients' Outcomes in Abdominal Wall Reconstruction Procedure

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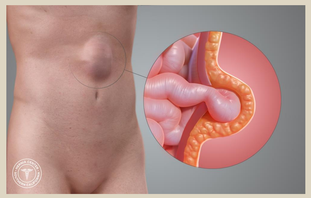
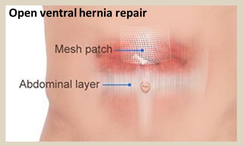
Background

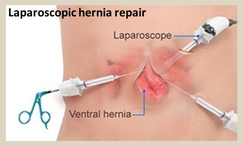
- A protrusion of abdominal tissue through a weak spot in the abdominal wall
  - Occurs at incision site of previous surgery
  - Caused by muscle weakness in abdomen
  - Smoking, obesity, and prior wound infections can increase risk



- Treatment Options and Impact:
  - Open ventral hernia repair: requires large, open incision; More than 50% result in recurrence



  - Laparoscopic ventral hernia repair: requires multiple smaller incisions; 13% to 24% complication rate



  - Nonsurgical management: Watchful waiting and lifestyle changes; only viable if showing no symptoms
  - Approximately 250,000 ventral hernia repairs performed each year
- Concerns:
  - Possible risk factors for wound complications reported:
    - Smoking, diabetes, obesity
    - Chronic steroid use and prolonged operation time
    - Surgery-specific factors (e.g., incision site, incision location)

Currently, there is no clear consensus on factors most contributing to post-op wound complications

Purpose

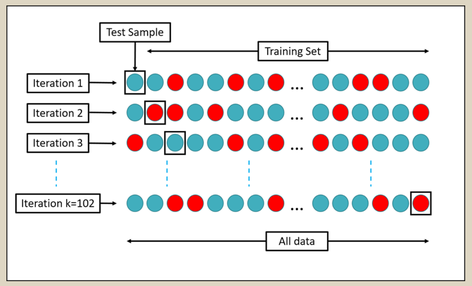
- Our goal is to develop a predictive model to
  - Identify the most contributing factors to wound complications following ventral hernia surgery
  - Stratify patients based on their outcomes

Data

- 102 patients' data collected over 49 months from 8/11 to 9/15 at Halifax Health in Daytona Beach, FL
- 73 total parameters recorded:
  - 23 patient characteristics (e.g. Age, BMI)
  - 37 intra-operative factors (e.g. OR Time, Incision Location)
  - 13 post-operative outcomes (e.g. Recurrence, Wound Complications)
- 29 total wound complications (nine major, seven moderate, 13 minor)

Methodology

- Built models using Random Forest
  - Very robust for datasets with high ratio of parameters to observations
  - Ensemble method
  - Uses bagging and random variable selection
  - Aggregates classification trees to predict response
  - Reduces overfitting of data
- Objectively evaluated the model using leave-one-out cross-validation

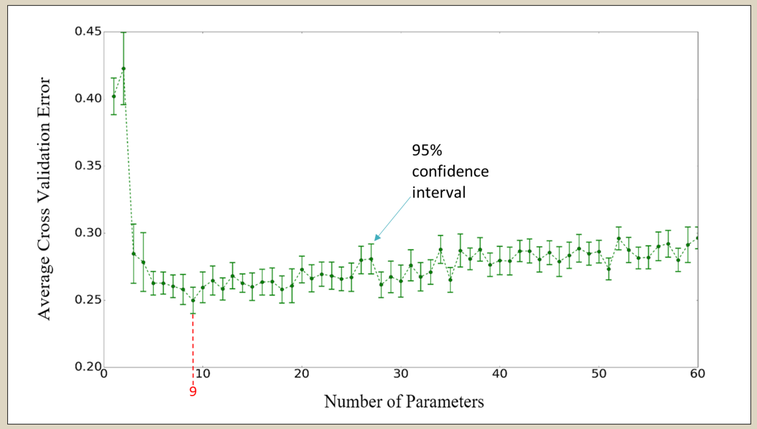


- **We observed poor classification accuracy when applied directly**
- Parameter Elimination (PE) Algorithm
  - Recursive parameter elimination approach that iteratively reduces number of parameters
  - Balancing to assure equal representation of the two classes of the response variable
  - Parameter selection based on Gini index

```
downsample with respect to the response variable to generate a balanced dataset ├ Balancing
while number of parameters in model is greater than zero do
   build RF using the balanced dataset ├ Random Forest
   identify the least important parameter using Gini index ├ Parameter Selection
   for each patient in the dataset do
      exclude the patient from the dataset and build RF for remaining patients in the dataset
      use RF to predict the response variable for the excluded patient
      determine if the predicted values match the ground truth or not for the excluded patient ├ CV
   end for
   calculate cross validation error by summing over the total number of incorrect
   predictions, divided by 102 and create a contingency matrix
   remove the least important parameter previously identified ├ Parameter Selection
end while
```

Best Model

- Executed PE algorithm 25 times to account for variations in each execution
- Nine-parameter models found to have highest F1 score out of all 60 n-parameter models



Results

$$F1\ Score = \frac{2TP}{2TP + FP + FN}$$

$$Sensitivity = \frac{TP}{TP + FN}$$

$$Specificity = \frac{TN}{FP + TN}$$

1. No Parameter Selection and No Balancing

	Predicted +	Predicted -
Condition +	3 (TP)	26 (FN)
Condition -	2 (FP)	71 (TN)
F1 Score ≈ 18%	**Sensitivity** ≈ 10%	**Specificity** ≈ 97%

2. Parameter Selection and No Balancing

	Predicted +	Predicted -
Condition +	13 (TP)	16 (FN)
Condition -	5 (FP)	68 (TN)
F1 Score ≈ 55%	**Sensitivity** ≈ 45%	**Specificity** ≈ 93%

3. No Parameter Selection and Balancing

	Predicted +	Predicted -
Condition +	22 (TP)	7 (FN)
Condition -	23 (FP)	68 (TN)
F1 Score ≈ 59%	**Sensitivity** ≈ 76%	**Specificity** ≈ 68%

4. Parameter Selection and Balancing

	Predicted +	Predicted -
Condition +	24 (TP)	5 (FN)
Condition -	17 (FP)	56 (TN)
F1 Score ≈ 69%	**Sensitivity** ≈ 83%	**Specificity** ≈ 77%

- Most important contributing parameters:
  - BMI
  - Age
  - OR Time
  - Wound Infection in Past
  - Number of Prior Abdominal Operations
  - Intra-Op Hernia Defect Size
  - Intra-Op Mesh Size
  - Pre-Op Emotional Complexity
  - Number of Prior Hernia Recurrences

Discussion

- Surprisingly, smoking did not show up as one of the main contributing factors to complications, despite anecdotal references in the literature and physicians' intuition
- Inform physicians and patients of the controllable factors and provide insights on the non-controllable factors
- Better understanding of risks and treatment options to inform physicians and patients to pave the way for shared decision making