Deep learning to predict post-operative mortality after cardiothoracic surgery using pre-operative chest radiographs

Vineet K. Raghu, PhD; Philicia Moonsamy, MD; Thoralf M. Sundt, MD; Chin Siang Ong, MBBS, PhD; Sanjana Singh; Alexander Cheng; Min Hou, MS; Linda Denning, BSN; Thomas G Gleason, MD; Aaron D. Aguirre, MD, PhD; and Michael T Lu, MD, MPH

Introduction

- Decisions whether to proceed with cardiothoracic surgery are made using the Society of Thoracic Surgeons (STS) Predicted Risk of Mortality (STS-PROM) risk score
- STS-PROM is time-intensive to calculate; requiring > 60 inputs
- STS-PROM only applies to ~65% of select procedures (e.g., coronary artery bypass, aortic valve replacement), called STS-Index procedures
- Deep learning models have been able to predict risk of long-term mortality and lung cancer from chest x-ray images.

Purpose

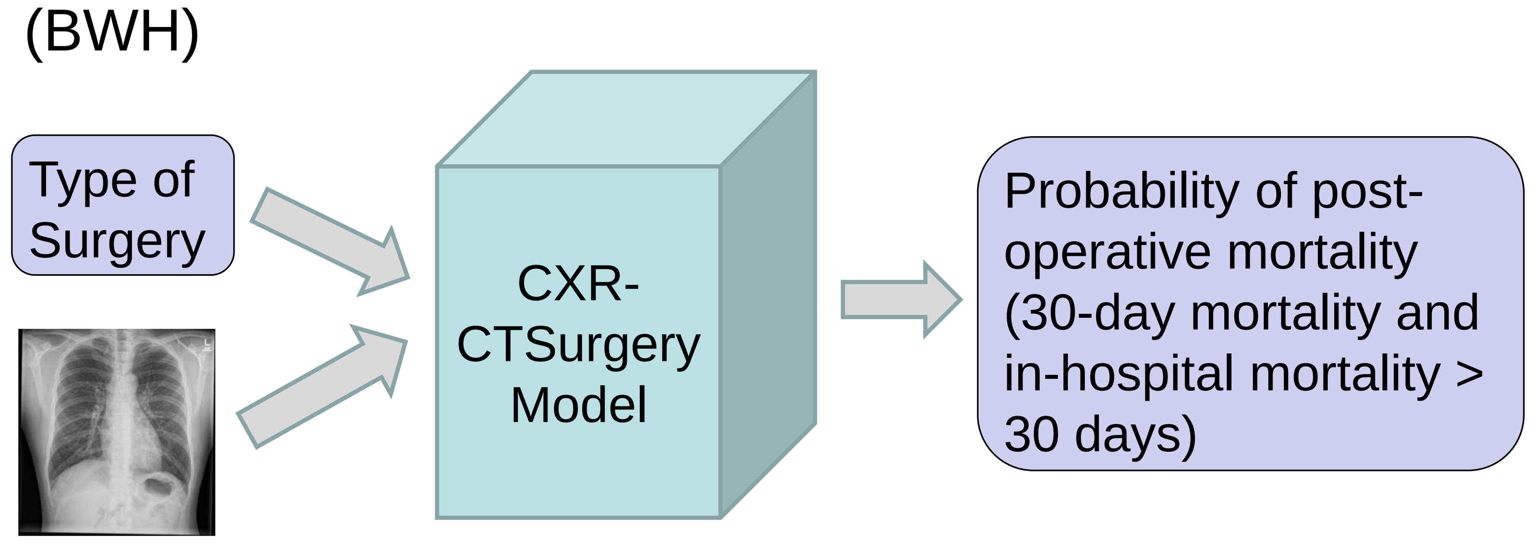
- To develop a deep learning model (CXR-CTSurgery) to predict postoperative mortality based on the pre-operative chest x-ray image
- To compare discrimination for postoperative mortality vs. the STS-PROM, for STS-Index procedures
- To assess whether CXR-CTSurgery retains high discrimination for non-STS-Index procedures

A deep learning model, CXR-CTSurgery can predict mortality after cardiac surgery with performance nearing the >60-risk factor clinical standard model, STS-PROM

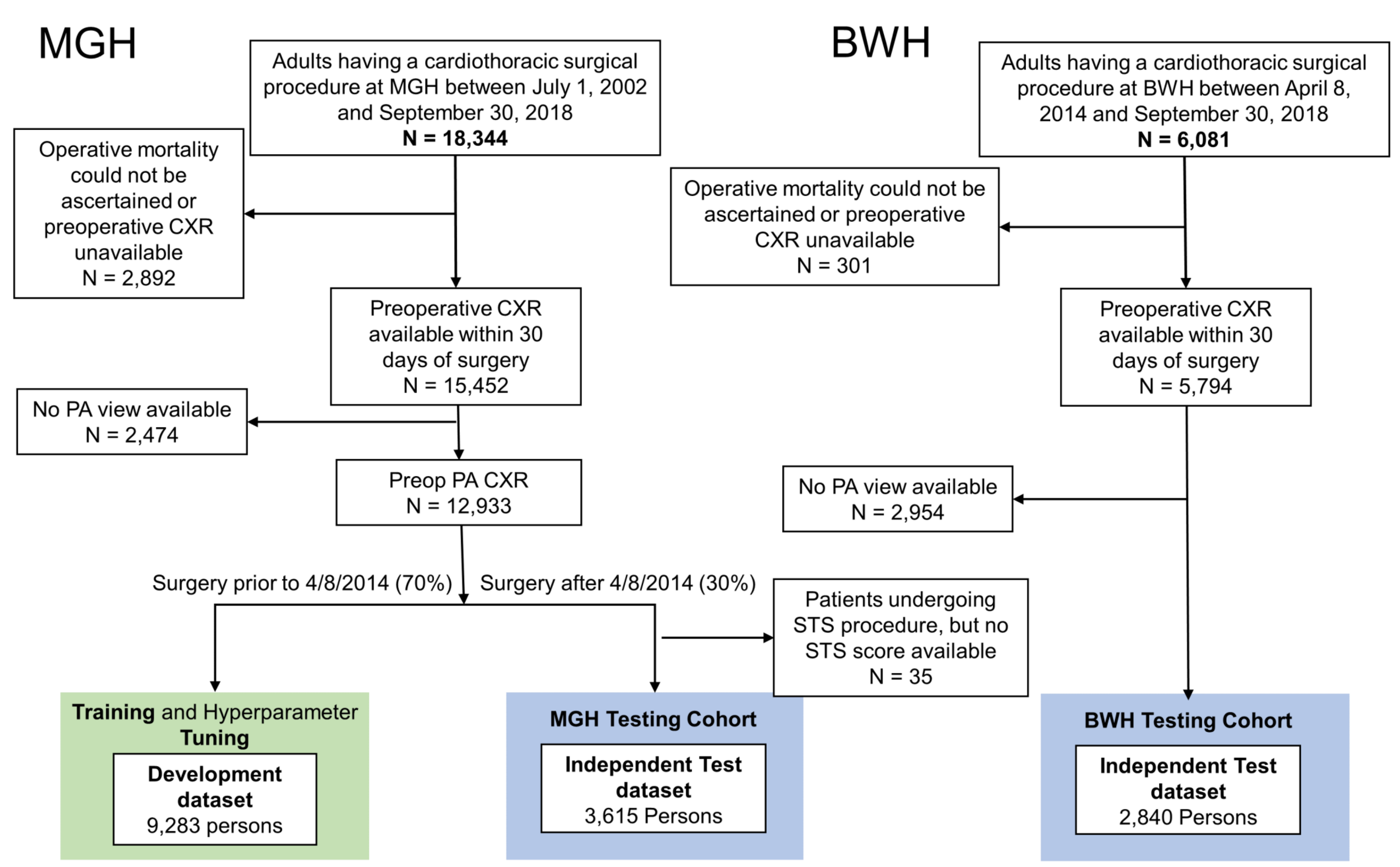
CXR-CTSurgery has high accuracy for the ~35% of cardiac surgeries not covered by the STS-PROM

Methods

- Patients undergoing cardiac surgery at Mass General Hospital (MGH) were split 70%-30% for developing and testing the model, respectively
- The model was tested in A) most recent 30% of surgeries at MGH, and B) surgeries at Brigham and Women's Hospital (BWH)



- CXR-CTSurgery was **developed** based on a previous model [1] (CXR-Risk) to predict 12-year all-cause mortality using transfer learning
- We first trained the model to predict any post-operative adverse event and then fine-tuned the model to predict postoperative mortality to increase the effective event rate



Future Work

External validation in more diverse cohorts at other institutions

Prospective pilot study to test whether CXR-CTSurgery can be used to help inform postoperative risk for patients undergoing non-STS-Index procedures

Results

Table 1: Development (left) and testing (right) cohort characteristics. Testing cohorts have reduced postoperative mortality and smoking rates

	MGH Development (N=9,283)	MGH Testing (N=3,615)	BWH Testing (N=2,840)
Age (y) mean (SD)	65.7 (13.8)	64.5 (13.3)	64.2 (12.3)
Male Sex (%)	6,310/9,282 (68 %)	2,584/3,615 (71.5 %)	1,935/2,840 (68.1 %)
Race			
Asian	184/8,802 (2.1 %)	114/3,489 (3.3 %)	52/2,723 (1.9%)
Black	158/8,802 (1.8 %)	81/3,489 (2.3 %)	92/2,723 (3.4%)
White	8,460/8,802 (96.1 %)	3,179/3,489 (91.1 %)	2,579/2,723 (94.7%)
Hispanic Ethnicity (%)	290/9,076 (3.2 %)	160/3,566 (4.5 %)	96/2675 (3.6%)
Obesity (%)	2,946/9,274 (31,8 %)	1,189/3,612 (32.9 %)	950/2,840 (33.4%)
Diabetes (%)	2,398/9,281 (25.8 %)	940/3,613 (26.0%)	751/2,840 (26.4 %)
Past MI (%)	1,547/5,561 (27.8 %)	890/3,592 (24.8 %)	524/2,840 (18.5 %)
Hypertension (%)	6,903/9,281 (74.4 %)	2,638/3,613 (73.0 %)	2,104/2,840 (74.1 %)
Dyslipidemia (%)	4,099/5,562 (73.7%)	2,635/3,593 (73.3%)	2,102/2,839 (74.0 %)
Heart Failure Class 3 or 4 (%)	2,611/4,698 (55.6%)	442/805 (54.9%)	480/957 (50.2 %)
Chronic Lung Disease (%)	1,335/9,271 (14.4%)	406/3,609 (11.2%)	371/2,839 (13.1 %)
Prior Cardiac Intervention (%)	2,730/9,280 (29.4 %)	1,104/3,612 (30.6 %)	894/2,840 (31.5 %)
Ever-Smokers (%)	3,088/4,422 (69.8 %)	1,830/3,399 (53.8 %)	1,415/2,726 (51.9%)
STS-PROM mean (SD)	3.2 (4.2)	2.0 (2.8)	1.7 (2.3)
Operative Mortality (%)	251/9283 (2.7%)	63/3,620 (1.7%)	67/2,840 (2.4%)

Table 2: Discrimination for operative mortality of a baseline demographic model (age, sex, race), CXR-CTSurgery, and STS-PROM for patients where STS-PROM could and could not be calculated.

	MGH Testing Cohort		BWH External Testing Cohort	
	Patients without an STS-PROM (N=1,315)	Patients with an STS-PROM (N=2,300)	Patients without an STS-PROM (N=935)	Patients with an STS-PROM (N=1,905)
Operative Mortality	39/1,315 (3.0%)	24/2,300 (1.0%)	43/935 (4.6%)	24/1,905 (1.3%)
Baseline Demographic Model AUC	0.712 (0.63,0.79)	0.589 (0.46,0.71)	0.546 (0.46,0.64)	0.612 (0.50,0.72)
CXR-CTSurgery AUC	0.874 (0.83, 0.92)	0.829 (0.72, 0.94)	0.727 (0.64,0.81)	0.738 (0.64,0.83)
STS-PROM AUC	NA	0.884 (0.82, 0.95)	NA	0.803 (0.71,0.90)

References and Acknowledgements

(1) Lu, MT et al. (2019). Deep learning to assess long-term mortality from chest radiographs. *JAMA Netw Open.*
(2) Shahian, DM et al. (2018). The Society of Thoracic Surgeons 2018 Adult Cardiac Surgery Risk Models: Part 1- Background, Design Considerations, and Model Development. *Annals of Thoracic Surgery.*
(3) O'Brien, SM et al. (2018). The Society of Thoracic Surgeons 2018 Adult Cardiac Surgery Risk Models: Part 2- Statistical Methods and Results. *Annals of Thoracic Surgery*
(4) Lu, MT*, Raghu, VK*, et al. (2020). Deep learning using chest radiographs to identify high-risk smokers for lung cancer screening computed tomography: development and validation of a prediction model. *Annals of Internal Medicine.*

This work was supported by NIH Grant T32HL076136, the Cardiovascular Imaging Research Center and the Massachusetts General Hospital's Department of Radiology

CARDIOVASCULAR IMAGING RESEARCH CENTER