

# Redundancy and Reliability Engineering in NSTEMI and A Two-Day Length of Stay

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## Summary

A paper in 2016 from Johns Hopkins University demonstrated that in the United States, the third-leading cause of death after coronary artery disease and cancer was medical error [1]. In contrast, transportation by commercial aviation is lauded as being safer than that by an automobile. One of the pillars of safety in engineering is fault tolerance, as even a perfect system cannot never fail. If the healthcare industry could achieve safety standards like those in the airline industry, morbidity and mortality could be decreased. While the human body is more complex than an airliner, that goal can nevertheless be strived toward. This case demonstrates how the last in a line of personnel identified an NSTEMI on the medical ward, the patient received percutaneous coronary intervention with placement of a drug-eluting stent and was discharged on the second day of hospitalization.

## Background

This case demonstrates the principle of (dual modular) redundancy as transferred from engineering to medical practice. As medicine inherently involves human/subjective variables more than aerospace engineering (e.g. this patient had tenderness to palpation, which does not point to a heart attack), collaboration between physicians and allied health personnel is key to safety and optimal outcomes.

## Case Presentation

A 77-year-old male with a past medical history of a leg deep vein thrombosis 17 years prior presented to the emergency department with nine out of ten intensity substernal chest pain. Current medications were aspirin 81mg and vitamin D. The patient was obese but high-performance status, physically active, a non-smoker, and had no family history of premature coronary artery disease. The pain started the day prior upon carrying a large bag of dog food, subsided, and then returned the morning of admission. It was alleviated by rest; there were no

provoking factors, and it radiated to the left shoulder. On physical exam, blood pressure was 209/92mm Hg and there was tenderness to palpation in the precordial area. Troponin-I was 0.32ng/mL (0.32µg/L, reference range < 0.03ng/mL) and CT pulmonary angiography was negative. The patient was evaluated by the emergency department physician and the cardiology physician assistant as requiring admission for a stress test. Given the business of the hospital on that day, the hospitalist resident admitted the patient over the phone and the patient was already on the medical ward by the time of the hospitalist's evaluation. On evaluation, the patient complained of persisting substernal pain which was better after reduction of blood pressure to 167/82mm Hg but still three out of ten. The resident re-stratified the patient as being intermediate TIMI risk for having  $\geq 3$  TIMI risk criteria [2], of which the patient had the following:

1. Age  $\geq 65$
2.  $\geq 2$  anginal episodes in the past 24 hours
3. Aspirin use in the past week
4. Troponin elevation of 0.32ng/mL (0.32 µg/L)

The resident then reevaluated and informed the patient he probably was having a heart attack and initiated metoprolol tartrate, captopril, antiplatelet therapy, heparin, atorvastatin, and called the cardiology physician assistant.

The following day, the patient underwent left heart catheterization which showed high-grade ulcerated plaque rupture of the proximal right coronal artery (RCA) with nearly complete stenosis (Figure 1). The proximal RCA was dilated and a 4x24mm drug-eluting stent was placed (Figure 2). The troponin-I was 6.86ng/mL (6.86µg/L).



**Figure 1:** The angiogram prior to revascularization demonstrates nearly complete stenosis of the right coronary artery (and right coronary dominance) as a result of rupture of an ulcerated plaque.



**Figure 2:** The angiogram after revascularization by percutaneous coronary intervention (balloon dilation) and placement of a 4x24mm everolimus-eluting stent in the proximal right coronary artery demonstrates restored patency.

On day two of hospitalization, the patient was feeling great and eager to go home. He was discharged before noon.

### Investigations

- Electrocardiogram
- CT pulmonary angiography
- Left heart catheterization and angiography

### Differential Diagnosis

- Accelerated hypertension (hypertensive emergency)
- Acute coronary syndrome (unstable angina or NSTEMI)
- Pulmonary embolus
- Thoracic aortic dissection
- Gastrointestinal source of pain
- Musculoskeletal source of pain
- Other

### Treatment

### Outcome and Follow-Up

Five months later, is on guideline-directed medical therapy and back to his normal activity. He has lost 40 pounds (18 kilograms/nearly three stones) and continues to diet and exercise.

## Discussion

Most acute coronary syndromes are detected by emergency department physicians and personnel. Whichever ACS are not picked up by the ED are usually caught by cardiology. But there is a small sliver that slip through unnoticed. Even the most experienced first and second-line evaluators cannot be expected to never miss a heart attack. In this case, it is up to the internist to be vigilant.

In order to transfer reliability engineering from the airline industry to medicine, which has much more human variables, it is probably important to emphasize a cooperative environment where colleagues are given the benefit of the doubt, anchoring bias is disabused, and closed-loop communication is employed. In this instance, the resident was not nervous about contacting the cardiology PA to voice his concerns, despite his view second guessing the emergency department and cardiology. As a result, the patient and everyone involved in his care had an excellent experience.

## Learning Points/Take Home Messages

- A collaborative environment is the foundation for reliability engineering in the healthcare setting.
- NSTEMI's are often diagnosed on the ward.
- The TIMI (thrombolysis in myocardial infarction) criteria are an easy and useful way for general practitioners to identify and risk stratify suspected NSTEMI and unstable angina: Patients with three or greater TIMI criteria would benefit from catheterization within 24 hours, whereas those with less than 3 TIMI criteria can be treated medically and with a stress test prior to discharge.

## References

1. Makary MA, Daniel M (2016) Medical error-the third leading cause of death in the US. *BMJ* 353.
2. Antman EM, Cohen M, Bernink PJ, McCabe CH, Horacek T, et al. (2000) The TIMI risk score for unstable angina/non-ST elevation MI: A method for prognostication and therapeutic decision making. *Jama* 284(7): 835-842.