Harvard-MIT Division of Health Sciences and Technology
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Computerized PAC Waveform Interpretation

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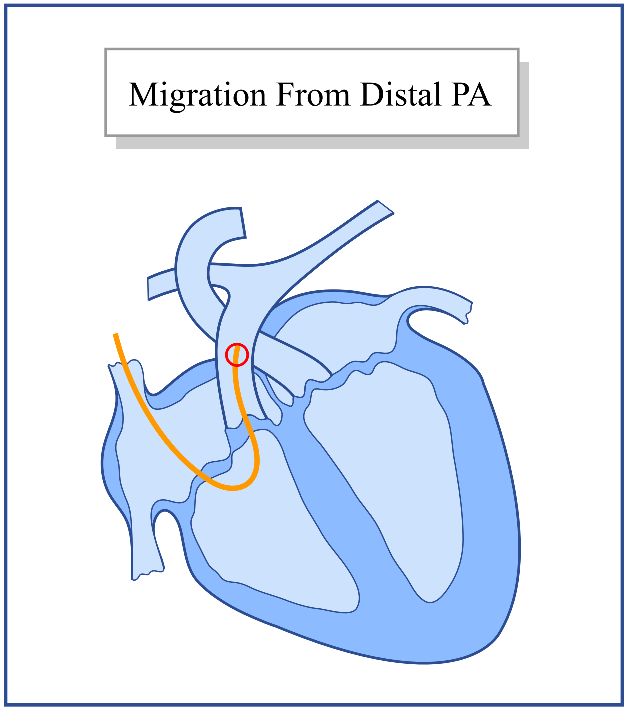
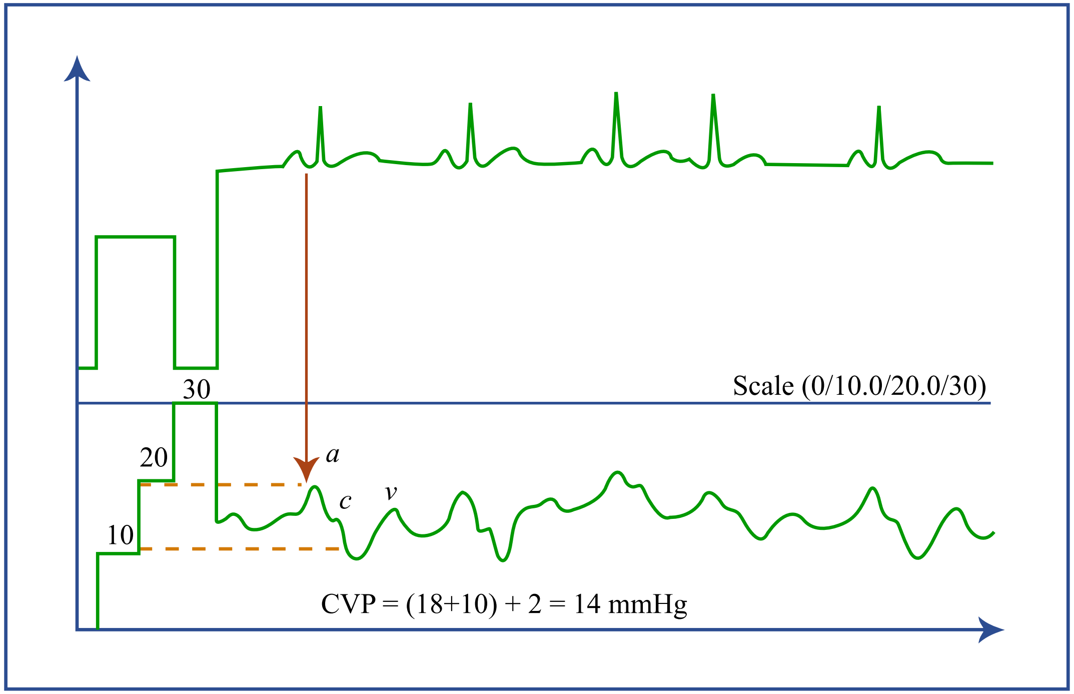
The Pulmonary Artery Catheter (PAC)

- The pulmonary artery catheter (PAC) has been used for decades in the diagnosis and treatment of critical care patients.
- The PAC is an invasive device used to measure the following:
  - cardiovascular pressures
  - cardiac output
  - mixed venous oxygen saturation

PAC Basics





Figures by MIT OCW.

Significance of the PAC

- Use of the PAC is considered routine in most critical care areas.
  - Estimated sales in the U.S. is 1 to 2 million per year.
- Data derived from the PAC alters the course of therapy in about half of all insertions.
  - Pulmonary artery occlusion pressure (PAOP), for instance, is used to decide whether to give or remove fluid volume from the patient.

The Problem

- Despite its long history of use, the PAC has never been shown to be beneficial in terms of outcomes.
- One possible explanation for this is the lack of knowledge among physicians and nurses in its use.
  - **Iberti et al. (1990):** 47% of 496 North American physicians did not correctly identify PAOP from a PAC trace.
  - **Gnaegi et al. (1997):** 50% of 535 European physicians did not correctly identify PAOP from a PAC trace.
  - **Burns et al. (1996):** 39% of 168 critical care nurses in California did not correctly identify PAOP from a PAC trace.

Computerized Waveform Interpretation

- Whereas computerized electrocardiogram (EKG) waveform interpretation has been available for decades, there is no equivalent software for PAC waveforms.
- Unlike in the case of the EKG, where almost all the necessary information is in the waveform itself, the interpretation of PAC waveforms is highly context-dependent.

PAC Waveform Context

- To properly interpret a PAC waveform, the following context information is required:
  - Source of the waveform (distal vs. proximal port)
  - Balloon status (deflated vs. inflated)
  - Accompanying EKG
  - Respiratory status (spontaneous respiration, positive pressure ventilation, or both)
  - Ventilator settings (if applicable)

PAC Waveform Elements

- Pre-processing analog PAC waveforms is a challenge, but suppose that such software already exists and can return to us the following basic PAC waveform elements:
  - Highest peak (HP) pressure
  - Lowest trough (LT) pressure
  - Difference between HP and LT
  - Midpoint between HP and LT
  - EKG rhythm (regular vs. irregular)
  - EKG location of peaks
  - Range of peaks
  - Range of troughs

Classes of Interest

- Dangerous vs. safe
  - Catheter tip (distal port) irritation of the right ventricle can cause a deadly arrhythmia.
  - Overwedge of an inflated balloon in a pulmonary artery may cause pulmonary infarction.
- Problem vs. no problem
  - All dangerous situations are problems.
  - System errors (such as underdamping, overdamping, inappropriate transducer level) are not immediately dangerous, but can contribute to improper treatment decisions.
- Source location (CVP, RV, PA, PAOP, Overwedge)
- System artifacts vs. abnormal physiology vs. normal

Data Set

- The data set includes 66 waveforms, each described by context, pre-processed waveform elements, and classification by experts.
  - **Danger:** 5 dangerous, 61 safe
  - **Problem:** 14 problems, 52 non-problems
  - **Location:** 18 CVP, 3 RV, 21 PA, 22 PAOP, 2 Overwedge
  - **Predominant Feature:**
    - 15 normal
    - 9 arrhythmias
    - 13 large waves
    - 14 respiratory variation
    - 11 frequency response artifacts
    - 1 improperly leveled transducer
    - 1 unspecified system artifact
    - 2 overwedge

Attribute Selection in Weka

- For each type of classification, use Ranker on the full data set to determine information value of each attribute.
- Discard attributes of zero information value.
  - **Danger:** discard peak variation, trough variation
  - **Problem:** discard lowest trough, trough variation
  - **Location:** discard peak variation, trough variation
  - **Feature:** discard lowest trough, HP-LT difference

Top Ranked Attributes

- Danger
  - Highest peak (0.15)
  - Lowest trough (0.12)
  - HP-LT midpoint (0.12)
- Problem
  - HP-LT difference (0.42)
  - Highest Peak (0.42)
  - HP-LT midpoint (0.35)
- Location
  - HP-LT midpoint (0.90)
  - Balloon status (0.87)
  - Highest peak (0.85)
- Feature
  - Trough variation (0.69)
  - Peak variation (0.65)
  - Peak location (0.65)

Classification Strategy

- Use 3-fold cross-validation for such a small sample size, so that the training and test sets are both of acceptable size.
- Compare classification with 1-nearest neighbor, decision tree, naïve Bayes, and neural network (multilayer perceptron).

Danger

- 5 of 66 waveforms (7.6%) are dangerous.

	Right %	Wrong %	Kappa	ROC	Significance (at 5% level)
Guess Safe	92.4	7.6			
Logistic Regression	92.4	7.6	0.40	0.84	No
Nearest Neighbor	95.5	4.5	0.64	0.79	No
DT	90.9	9.1	0.20	0.65	No
Bayes	87.9	12.1	0.27	0.88	No
Multilayer Perceptron	95.6	4.5	0.55	0.89	No

Location

- 22 of 66 waveforms (33.3%) are PAOP.

	Right %	Wrong %	Kappa	ROC (PAOP)	Significance (at 5% level)
Guess PAOP	33.3	66.7			
Nearest Neighbor	92.4	7.6	0.89	0.94	No
DT	90.9	9.1	0.87	0.96	No
Bayes	86.4	13.6	0.81	0.94	No
Multilayer Perceptron	92.4	7.6	0.89	0.99	No