**Part E**

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# 23.1: Introduction

Clinical datasets represent years of work collecting cases, truthing them (this is often the most time consuming part as patients do not come conveniently labeled as diseased or non-diseased), designing the study and fine tuning the logistics for acquiring the data, cajoling radiologists to interpret the cases (radiologists, as everyone nowadays, but perhaps more so, are notoriously overworked), analyzing the data, and finally trying to publish the results. Over his professional career, spanning 40 years, which have included a large number of mostly international collaborations, the author has collected many datasets, a sampling of which is being made available as part of RJafroc. These are intended allow researchers to understand the analytical methods and perhaps develop improved methodology for analyzing the datasets.

Clinical datasets are the real thing. Simulations are useful to test the internal consistency of an analysis method, but the simulated datasets are not guaranteed to represent, in statistical characteristics, real clinical datasets.

Several datasets are included in the online software. These were invaluable to the author in developing methodology, particularly for RSM curve fitting.

# 23.2: The datasets

The datasets are contained in the online Datasets directory corresponding to this chapter. The summary of the datasets, Table 19.1, can be viewed by sourcing file mainDataSummary.R. Characteristics of the datasets can be examined by running the code in debug mode, e.g. by inserting a breakpoint at line 28 and sourcing the file. The datasets are contained in the online directory book/06 E Appendices/E23 Datasets. Four of these are ROC datasets, one an LROC dataset and the rest (nine) are FROC datasets. For non-ROC datasets prior to fitting, the highest rating method was used to infer the corresponding ROC data.

Table 19.1: This table lists the summary characteristics of the datasetsw used in this book. The dataset type is ROC, FROC or LROC. The total number of individual modality-reader combinations is 236. [I = # modalities, J = # readers, K1 = number of non-diseased cases, K2 = number of diseased cases; TOT = total.]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dataset #** | **Dataset Name** | **Data**  **Type** | **I** | **J** | **K1** | **K2** | **K** | **Description** |
| 1 | TONY[1](#_ENREF_1) | FROC | 2 | 5 | 96 | 89 | 185 | Digital breast tomosynthesis vs. mammography |
| 2 | VD[2](#_ENREF_2) | ROC | 2 | 5 | 69 | 45 | 114 | Cine vs. SE MRI for aortic dissection |
| 3 | FR[3](#_ENREF_3) | ROC | 2 | 4 | 33 | 67 | 100 | Digital vs. analog pediatric chest |
| 4 | FED[4](#_ENREF_4) | FROC | 5 | 4 | 100 | 100 | 200 | Image processing in mammography: FROC |
| 5 | JT[5](#_ENREF_5) | FROC | 2 | 9 | 45 | 47 | 92 | Nodule detection in an thorax CT phantom |
| 6 | MAG[6](#_ENREF_6) | FROC | 2 | 4 | 47 | 42 | 89 | Tomosynthesis Vs. Radiography Pulmonary Nodules |
| 7 | OPT[7](#_ENREF_7) | FROC | 5 | 7 | 81 | 81 | 162 | Calcification detection in digital mammography |
| 8 | PEN[8](#_ENREF_8) | FROC | 5 | 5 | 48 | 64 | 112 | Image compression in mammography |
| 9 | NICO[9](#_ENREF_9) | LROC | 1 | 10 | 120 | 80 | 200 | Standalone CAD vs. radiologists mammography |
| 10 | RUS[10](#_ENREF_10) | FROC | 3 | 8 | 50 | 40 | 90 | Lesion detection in digital mammography |
| 11 | DOB1[11](#_ENREF_11) | FROC | 4 | 5 | 43 | 115 | 158 | Tomosynthesis, Dual-Energy & Conventional Chest |
| 12 | DOB2[11](#_ENREF_11) | ROC | 4 | 5 | 64 | 88 | 152 | do: |
| 13 | DOB3[11](#_ENREF_11) | FROC | 4 | 5 | 52 | 106 | 158 | do: |
| 14 | FZR[12](#_ENREF_12) | ROC | 2 | 4 | 100 | 100 | 200 | Image processing in mammography: ROC |
|  | | | | | | | | |
| TOT |  | | 43 | 80 | 948 | 1064 | 2012 |  |

## 23.2.1: A breast tomosynthesis dataset

**Dataset #1**: "TONY": Dr. Tony Svahn conducted a clinical MRMC FROC study[1](#_ENREF_1) in which 5 radiologists interpreted 96 non-diseased and 89 breast imaging cases in two modalities. Modality 1 was single-view 3D breast tomosynthesis and modality 2 was 2D digital mammography. Details of the study and analysis are in a SPIE proceedings paper[13](#_ENREF_13), a pre-publication copy of which, TonyDevSPIE2011.pdf, is included in the online supplementary material. There are several other publications by Svahn et al in breast tomosynthesis[14](#_ENREF_14),[15](#_ENREF_15).

## 23.2.2: The Van Dyke dataset

**Dataset #2**: "VD" (Dr. Carolyn Van Dyke, MD). Dr. Van Dyke conducted an MRMC ROC study[2](#_ENREF_2) comparing single spin-echo magnetic resonance imaging and cine MRI in detecting thoracic aortic dissection. There were 45 patients with an aortic dissection[[1]](#footnote-1) and 69 patients without dissection. Each patient was imaged with both SE-MRI (modality 1) and cine-MRI (modality 2). Five radiologists interpreted all of the images using a 5-point positive directed rating scale. The data file is named VanDyke.lrc. The "lrc" format is described in the document "OR DBM MRMC 2.4 User Guide", authored by Steve Hillis, Kevin Schartz and Kevin Berbaum, on the University of Iowa ROC website. This dataset, and the following one, are well known in the ROC methodology field, because they have been used repeatedly to illustrate the evolution of ROC analysis methods.

## 23.2.3: The Franken dataset

**Dataset #3**: "FR" Dr. Franken et al[3](#_ENREF_3) compared diagnostic accuracy of interpreting clinical neonatal chest and abdominal radiographs for signs of diseased, using a picture archiving and communication system (PACS) workstation (modality 1) versus plain film (modality 2). This was acquired in the early days of digital imaging technology, when there were doubts whether the limited spatial resolution of digital would be good enough to match mature analog film/screen technology. The case sample consisted of 100 chest or abdominal radiographs (67 diseased and 33 non-diseased). The readers were four radiologists with considerable experience in interpreting neonatal examinations. The readers rated each patient image on a 5-point positive directed integer scale. The data file is named Franken1.lrc.

## 23.2.4: The Dr. Federica Zanca dataset (FROC)

**Dataset 4**: This is a 5 modality 4 radiologist dataset[4](#_ENREF_4) acquired by Dr. Federica Zanca. The 5 modalities are different image processing methods applied to 100 non-diseased single view mammograms and 100 simulated diseased single-view mammograms constructed by superposing microcalcification cluster profiles. All diseased cases are simulated microcalcifications created by superposing high-resolution images of thin-section excised breast specimens of biopsy-proven microcalcifications on non-diseased cases[16](#_ENREF_16).

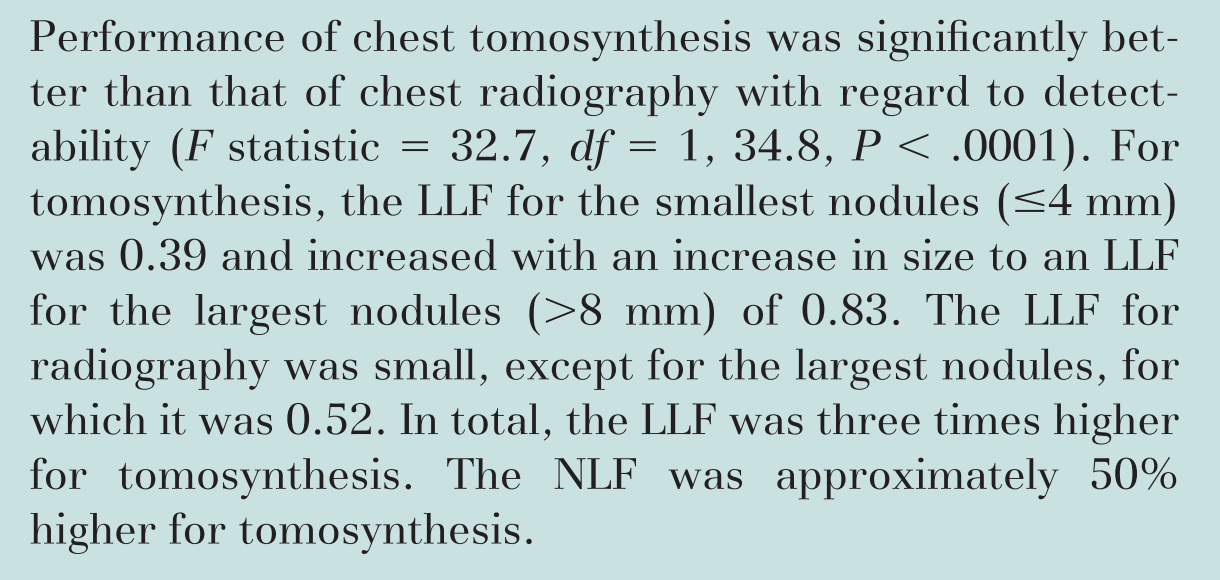
## 23.2.5: The Dr. John Thompson dataset

**Dataset 5**: This study evaluated nodule detection in an anthropomorphic chest phantom in computed tomography (CT). The phantom was scanned at 4 values of mAs (10, 20, 30, and 40) and images were reconstructed with both adaptive iterative dose reduction 3D (AIDR3D) and filtered back projection (FBP). Thus there are *two treatment* factors and the factors are *crossed* since for each value of the mAs factor there were two values of the reconstruction algorithm factor. This is referred to in the code as the "JT" dataset. A good example of the latter is studies conducted with phantoms[5](#_ENREF_5),[17](#_ENREF_17). In the cited studies an anthropomorphic chest phantom (Lungman N1 Multipurpose Chest Phantom, Kyoto Kagaku Company, Japan; <https://www.kyotokagaku.com/products/detail03/ph-1.html>) representing a 70Kg male was loaded with simulated nodular lesions of different sizes and contrasts. This phantom allows insertion of lesions inside the chest cavity, so effects of vasculature overlap and mimicking of lesions are simulated. But there is only one such phantom, manufactured to strict quality control standards assuring that all copies are identical. In this situation the concept of extrapolating to the populations of phantoms is implausible. Therefore, with phantom studies one should only report random-reader fixed-case analysis.

## 23.2.6: The Dr. Magnus Bath dataset

**Dataset 6**: This is referred to in the code as the "MAG" dataset.[6](#_ENREF_6)

To compare chest tomosynthesis with chest radiography in the detection of pulmonary nodules by using multidetector computed tomography (CT) as the reference method. The Regional Ethical Review Board approved this study, and all participants gave informed consent. Four tho- racic radiologists acted as observers in a jackknife free- response receiver operating characteristic (JAFROC) study conducted in 42 patients with and 47 patients without pulmonary nodules examined with chest tomo- synthesis and chest radiography. Multidetector CT served as reference method. The observers marked sus- pected nodules on the images by using a four-point rating scale for the confidence of presence. The JAFROC figure of merit was used as the measure of detectability. The number of lesion localizations relative to the total number of lesions (lesion localization fraction [LLF]) and the number of nonlesion localizations relative to the total number of cases (nonlesion localization fraction [NLF]) were determined. Performance of chest tomosynthesis was significantly bet- ter than that of chest radiography with regard to detect- ability (F statistic ? 32.7, df ? 1, 34.8, P ? .0001). For tomosynthesis, the LLF for the smallest nodules (?4 mm) was 0.39 and increased with an increase in size to an LLF for the largest nodules (?8 mm) of 0.83. The LLF for radiography was small, except for the largest nodules, for which it was 0.52. In total, the LLF was three times higher for tomosynthesis. The NLF was approximately 50% higher for tomosynthesis. For the detection of pulmonary nodules, the performance of chest tomosynthesis is better, with increased sensitivity especially for nodules smaller than 9 mm, than that of chest radiography. ? RSNA, 2008 Radiology:



## 23.2.7: The OPTIMAM dataset

**Dataset 7**: This is referred to in the code as the "OPT" dataset.[7](#_ENREF_7) Threshold gold thickness at five different image qualities: DR at normal, half, and quarter dose levels shown with disc points, and CR at normal and half dose levels shown with square points: (a) 0.1 mm gold disc diameter and (b) 0.25 mm gold disc diameter. Acceptable and achievable standards as set in the European protocol (Ref. 15) are also shown along with dose limit for a breast thickness equivalent to 50 mm PMMA. Quarter dose left out of file

> print(ret$ciAvgRdrEachTrtRRRC)

Treatment Area StdErr DF CI Lower CI Upper

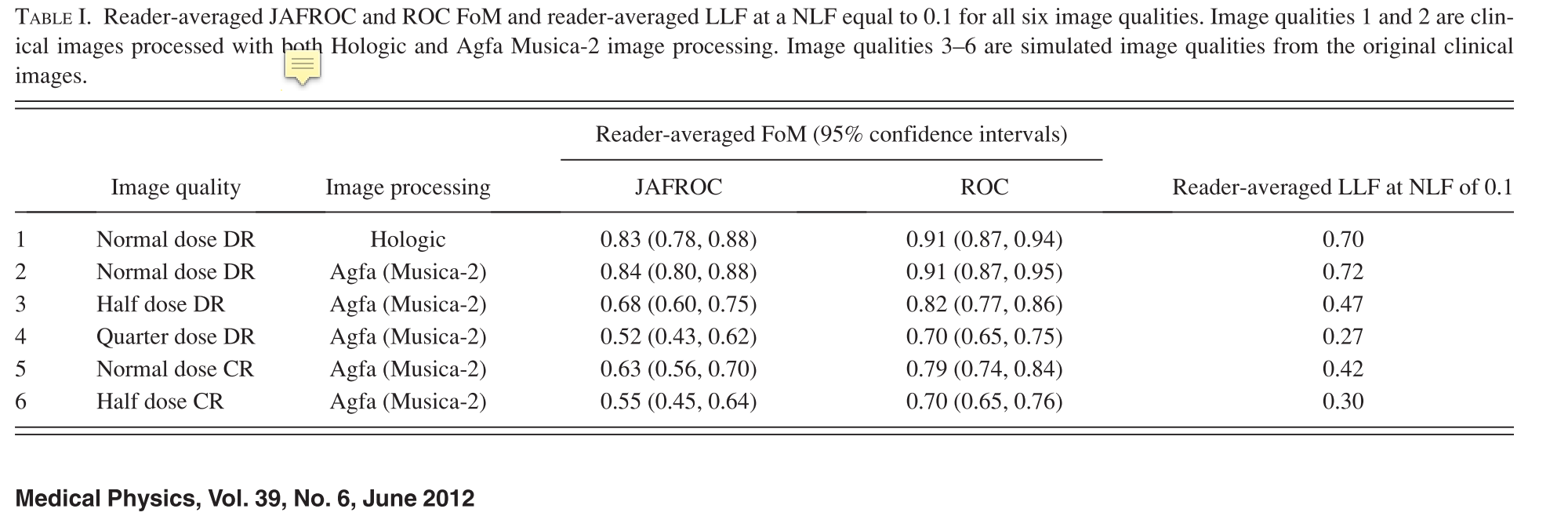
1 1 0.8313434 0.02375184 44.11423 0.7834782 0.8792085

2 2 0.6334379 0.03356088 26.95101 0.5645708 0.7023050

3 3 0.6768897 0.03504769 21.65440 0.6041379 0.7496415

4 4 0.5461831 0.04209587 12.34044 0.4547440 0.6376223

5 6 0.8367514 0.01999903 38.31947 0.7962766 0.8772263

****

## 23.2.8: The Dr. Monica Penedo dataset

**Dataset 8**: This is referred to in the code as the "PEN" dataset.[8](#_ENREF_8)

MATERIALS AND METHODS: The use of the images in this retrospective image- collection study was approved by the institutional review board, and patient in- formed consent was not required. One hundred twelve mammographic images (28 with one or two clusters of microcalcifications, 19 with one mass, 17 with both abnormal findings, and 48 with normal findings) obtained in 60 women who ranged in age from 25 to 79 years were digitized and compressed at 40:1 and 80:1 by using the JPEG2000 and object-based SPIHT methods. Five experienced radiol- ogists were asked to locate and rate clusters of microcalcifications and masses on the original and compressed images in a free-response receiver operating characteristic (FROC) data acquisition paradigm. Observer performance was evaluated with the jackknife FROC method. RESULTS: The mean FROC figures of merit for detecting clusters of microcalcifi- cations, masses, and both radiographic findings on uncompressed images were 0.80, 0.81, and 0.72, respectively. With object-based SPIHT 80:1 compression, the corresponding values were larger than the values for uncompressed images by 0.005, 0.009, and ?0.005, respectively. The 95% confidence interval for the differences in figures of merit between compressed and uncompressed images was ?0.039, 0.033 for the microcalcification finding; ?0.055, 0.034 for the mass finding; and ?0.039, 0.030 for both findings. Because each of these confidence intervals includes zero, no significant difference in detection accuracy between uncompressed and object-based SPIHT 80:1 compression was observed at a P value of 5%. The F test of the null hypothesis that all of the modes (uncompressed and four compressed modes) were equivalent yielded the following results: F ? 0.255, P?.903 for the microcalcification finding; F?0.340, P?.848 for the mass finding; and F ? 0.122, P ? .975 for both findings.

fileName = PEN

Treatment Area StdErr DF CI Lower CI Upper

1 0 0.8239583 0.03705225 15.83284 0.7453436 0.9025730

2 1 0.8160482 0.03124021 21.52732 0.7511774 0.8809190

3 2 0.8152018 0.04007620 15.44054 0.7299932 0.9004104

4 3 0.8201497 0.03620888 14.42060 0.7427014 0.8975981

5 4 0.8042969 0.03875517 17.17770 0.7225950 0.8859987

## 23.2.9: The Dr. Nico Karssemeijer dataset

**Dataset 9**: This is referred to in the code as the "NICO" dataset. The study[9](#_ENREF_9), also referred to as the *Hupse-Karssemeijer study*, compared standalone performance of a CAD device to that of 9 radiologists interpreting the same cases (120 non-diseased and 80 with a single malignant mass per diseased case) using the location receiver operating characteristic (LROC) paradigm[18-21](#_ENREF_18). In LROC for each case the radiologist gives an overall rating for presence of disease, i.e., an ROC rating, and indicates the location of the most suspicious region. On non-diseased cases the rating is classified as a false positive rating (i.e., the location is ignored), but on a diseased case the rating is classified as a *correct localization* if the mark is sufficiently close to the lesion, otherwise it is classified as an *incorrect localization*.

## 23.2.10: The Dr. Mark Ruschin dataset

The third dataset is a recently conducted study on which the author acted as the statistical consultant.

**Dataset 10**: This is referred to in the code as the "DOB1" dataset. Dobbins et al.[11](#_ENREF_11) conducted a multi-institutional, MRMC study to compare the performance of digital tomosynthesis (GE's VolumeRad device), dual-energy (DE) imaging, and conventional chest radiography for pulmonary nodule detection and management. All study images were obtained with a flat-panel detector developed by GE. The case set consisted of 158 subjects, of which 43 were non-diseased and the rest had 1 – xx pulmonary nodules independently verified, using with CT images, by 3 experts who did not participate in the observer study. The patients were enrolled at four institutions and the readers came from different institutions. The detection study used FROC paradigm data collection. The outcome study, on a 5-point scale, used ROC paradigm data collection. The data file is named CXRinvisible3-20mm.xlsx. The Excel data format accommodates all paradigms in current usage: ROC, FROC, LROC and ROI. The format is described in documents available on the author's website, [www.devchakraborty.com](http://www.devchakraborty.com), and in the RJafroc package documentation, <https://cran.r-project.org/web/packages/RJafroc/index.html>. For this dataset[22](#_ENREF_22)

there are 4 modalities labeled 1 – 4:

1. 2-view digital chest x-rays (CXR) with a flat-panel detector;
2. CXR + dual energy images (DE);
3. Chest tomosynthesis images (TOMO) with the GE's VolumeRad device, and
4. TOMO + DE.

A *pdf* file "GEHealthcare-Education-TiP-App-Library\_XR-Volume-Rad-Quicksteps.pdf" describing VolumeRad is included in the software directory. It has a good description of how it works.

## 23.2.11: The VolumeRad dataset #1

**Dataset 11**: This contains action-ability ROC data from the Dobbins et al.[22](#_ENREF_22) study described above. Each reader was asked if the case ought to be considered *actionable*, i.e., needed further investigation. The data file is named actionability.xlsx. As with dataset 3, there are 4 modalities labeled 1 – 4 as described for dataset 3. Data was acquired on a 4-point positive directed scale. This is referred to in the code as the "DOB2" dataset.

Table 23.1: Summary characteristics of datasets used in this book. [I = # modalities, J = # readers, K1 = number of non-diseased cases, K2 = number of diseased cases.]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dataset #** | **Dataset Name** | **Type** | **I** | **J** | **K1** | **K2** | **K** | **Comments** |
| **Dataset #** | **Dataset Name** | **Type** | **I** | **J** | **K1** | **K2** | **K** | **Comments** |
| 1 | TONY[1](#_ENREF_1) | FROC | 2 | 5 | 96 | 89 | 185 |  |
| 2 | VD[2](#_ENREF_2) | ROC | 2 | 5 | 69 | 45 | 114 |  |
| 3 | FR[3](#_ENREF_3) | ROC | 2 | 4 | 33 | 67 | 100 |  |
| 4 | FED[4](#_ENREF_4) | FROC | 5 | 4 | 100 | 100 | 200 |  |
| 5 | JT[5](#_ENREF_5) | FROC | 2 | 9 | 45 | 47 | 92 |  |
| 6 | MAG[6](#_ENREF_6) | FROC | 2 | 4 | 47 | 42 | 89 |  |
| 7 | OPT[7](#_ENREF_7) | FROC | 5 | 7 | 81 | 81 | 162 |  |
| 8 | PEN[8](#_ENREF_8) | FROC | 5 | 5 | 48 | 64 | 112 |  |
| 9 | NICO[9](#_ENREF_9) | LROC | 1 | 10 | 120 | 80 | 200 |  |
| 10 | RUS[10](#_ENREF_10) | FROC | 3 | 8 | 50 | 40 | 90 |  |
| 11 | DOB1[22](#_ENREF_22) | FROC | 4 | 5 | 43 | 115 | 158 |  |
| 12 | DOB2[22](#_ENREF_22) | ROC | 4 | 5 | 64 | 88 | 152 |  |
| 13 | DOB3[22](#_ENREF_22) | FROC | 4 | 5 | 52 | 106 | 158 |  |

dsfakjlaskl 0.1

## 23.2.12: The VolumeRad dataset #2

**Dataset 11**: This contains action-ability ROC data from the Dobbins et al.[22](#_ENREF_22) study described above. Each reader was asked if the case ought to be considered *actionable*, i.e., needed

## 23.2.13: The VolumeRad dataset #3

**Dataset 11**: This contains action-ability ROC data from the Dobbins et al.[22](#_ENREF_22) study described above. Each reader was asked if the case ought to be considered *actionable*, i.e., needed

## 23.2.14: The Dr. Federica Zanca dataset (ROC)

**Dataset 11**: This contains action-ability ROC data from the Dobbins et al.[22](#_ENREF_22) study described above. Each reader was asked if the case ought to be considered *actionable*, i.e., needed

# 23.11: Discussion / Summary

# 9.15 References

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(9.24) ddf

(9.34)

(9.35) Eqn. for AH-RRRC

(9.43)

(9.44)

(9.52)

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Fig. 12.A.1

Fig. 12.B.1

Fig. 12.B.2

Table 12.1

12.A.1

12.6

Chapter 13

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Fig. 13.2

Fig. 13.3

Fig. 13.4

Fig. 13.5

Fig. 13.6

Fig. 13.7

Fig. 13.8

Fig. 13.9

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13.4.1

13.16.2

13.10.1

13.10.3.1

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13.10.5.1

13.15.1

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13.12.1

13.11.1

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Fig. 15.1

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Fig. 15.4

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Fig. 15.A.1

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Fig. 17.1

Fig. 17.2

Fig. 17.3

Fig. 17.4

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Fig. 17.7

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Fig. 17.9

Fig. 17.10

Table 17.3

17.5.1

17.5.2

17.6.1

17.6.2

17.7.2

17.8 Search performance

17.9 Class. Performance

17.10 IsFrocGood

17.10.1 Clinical relevance

17.11.2.1 Eng Code

17.11

demo

17.11.4

Table 17.1

Table 17.2

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Fig. 18.3

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Table 18.2

Table 18.3

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19.5.3

19.5.4

Fig. 19.1

Fig. 19.2

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Fig. 19.4

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Fig. 19.6

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Fig. 19.11

Fig. 19.12

Table 19.1

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Online Appendix 19.C.8

20.7.2.1

Fig. 20.1

Fig. 20.2

Fig. 20.3

Fig. 20.4

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Fig. 20.6

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Fig. 21.2

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Fig. 21.5

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Fig. 21.D.2

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Fig. 21.D.5

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Table 22.1

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Table 22.3

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22.2.1.1

22.2.1.2

22.2.1.3

22.2.1.4

Fig. 22.1

Fig. 22.2

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23.A.1

Online Table 23.1

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# Cross-references

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**Part B**

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**Chapter 02**

**Chapter 03**

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Online Appendix

Online Appendix 1.A

Fig. 1.1

Figure 1.A.4

Figure 1.A.5.1

Figure 1.A.5.2

Figure 1.A.5.2

Figure 1.A.5.1.2

2.9.2 PPV NPV

Table 2.1

Table 2.2

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Fig. 3.1

Fig. 3.2

Fig. 3.3

Fig. 3.A.2

Fig. 3.H.2.1

Fig. 3.H.2.2

Fig. 3.E.1

Fig. 3.4

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Fig. 3.6 beam et al study

Fig. 3.G.3

Fig. 3.C.4

Fig. 3.A.2

Fig. 3.C.1

Fig. 3.E.1

Fig. 3.G.2

Fig. 3.G.3

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Fig. 3.H.2.1

Fig. 3.I.2

3.10

Table 3.2

Table 3.3 beam et al study

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Online Appendix 3.E Getting help in R-I

Online Appendix 3.F Getting help in R-II

Online Appendix 3.G

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Fig. 4.1

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Fig. 4.3

Table 4.1 Roc counts table

Table 4.2

Table 4.3

Table 4.4

Table 4.5

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Fig. 5.1 operating point convention

Fig. 5.2

Fig. 5.3

Table 5.1

Table 5.2

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Fig. 6.1

Fig. 6.2

Fig. 6.3

Fig. 6.4

Fig. 6.5

Appendix 6.A

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6.2.6

6.4.2

Table 6.1

Table 6.2

Table 7.1

Table 7.2

Table 7.3

7.3.2

Fig. 7.1

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Online Appendix 7.B

Online Appendix 7.C

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Online Appendix 7.E

Eqn.(7.6)

Fig. 8.1

Table 8.1

Fig. 9.1

Fig. 9.2

Fig. 9.3

Fig. 9.4

Fig. 9.5

(9.24) dds

(9.34) Definition of ncp

(9.35) Eqn. AH – RRRC

(9.24)

(9.34)

(9.35)

(9.43)

(9.44)

(9.43)

(9.44)

(9.52)

(9.53)

9.10.2.2 Interactions

Table 9.1

Table 9.2

Table 9.3

Table 9.4

Table 9.5

Table 9.6

Table 9.7

Table 9.7

Table 9.8

9.13: Meaning of pseudovalues

Fig. 9.A.2

Fig. 9.A.3.1

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Table 9.E.1

Table 9.H.1

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10.2.5.1

10.2 1RIT

Fig. 10.1

Fig. 10.2

10.5.1

10.7 1TMultipleR

10.2.4 Meaning of Cov matrix

Online Appendix 10.A

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Table 11.1 2 types of errors

Fig. 11.1

11.8.1

11.8.4

Fig. 11.2

Fig. 11.3

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Table 11.2

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Fig. 12.B.2

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Table 9.H.1

Table 13.1 FROC notation

Table 13.2

Table 13.3

Table 13.4

Table 13.5

Fig. 13.1

Fig. 13.2

Fig. 13.3

Fig. 13.4

Fig. 13.5

Fig. 13.6

Fig. 13.7

Fig. 13.8

Fig. 13.9

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13.4.1

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13.10.3.1

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13.10.5.1

13.15.1

13.15

Appendix 13.A.1

13.11.1

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13.11.3

13.12.1

13.13.1

Table 14.C.1

Fig. 14.1

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Table 14.1

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Fig. 15.1

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Fig. 15.3

Fig. 15.4

Fig. 15.6

Fig. 15.7

Fig. 15.7

Fig. 15.A.1

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Table 16.1

16.4

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17.3

Fig. 17.1

Fig. 17.2

17.5.1

17.5.2

Fig. 17.3

Fig. 17.4

Fig. 17.5

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Fig. 17.7

Fig. 17.8

Fig. 17.9

Fig. 17.10

Table 17.1

Table 17.2

Table 17.3

17.5.1

17.5.2

17.6.1

17.6.2

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17.10.1

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17.11.4

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Fig. 18.1

Fig. 18.2

Fig. 18.3

Fig. 18.3

Table 18.1

Table 18.2

Table 18.3

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19.2.3

19.7 Sample size

19.5

19.5.2

19.5.3

19.5.4

Fig. 19.1

Fig. 19.2

Fig. 19.3

Fig. 19.4

Fig. 19.5

Fig. 19.6

Fig. 19.7

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Fig. 19.11

Fig. 19.12

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Table 19.3

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Online Appendix 19.A.3

Online Appendix 19.A.4

Online Appendix 19.A.3

Online Appendix 19.A.4

Online Appendix 19.C

Online Appendix 19.C.1

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20.7.2.1

Fig. 20.1

Fig. 20.2

Fig. 20.3

Fig. 20.4

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Fig. 20.6

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Table 20.1

Table 20.2

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Fig. 21.D.2

Fig. 21.D.3

Fig. 21.D.4

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Fig. 21.D.6

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Table 22.1

Online Appendix 22.A

Online Appendix 22.B

22.2.1.1

22.2.1.2

22.2.1.3

22.2.1.4

Fig. 22.1

Fig. 22.2

Table 22.2

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Table 22.3

23.A.1

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5/3/17 11:44:12 AM

1. Aortic dissection is separation of the layers within the aortic wall. Tears in the intimal layer result in the propagation of dissection (proximally or distally) secondary to blood entering the intima-media space. Mortality is still high despite advances in diagnostic and therapeutic modalities (http://emedicine.medscape.com/article/2062452-overview). [↑](#footnote-ref-1)