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Medical Imaging.
Clinical Importance & Interpretation Issues

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1. Medical Imaging

1.1.The engineering view

- Medical imaging is the most important source of anatomical and functional information, which is indispensable for today's clinical research, diagnosis and treatment, and is an integral part of modern healthcare.

Patias P. Medical Imaging challenges Biostereometrics: A new era of Medical Photogrammetry

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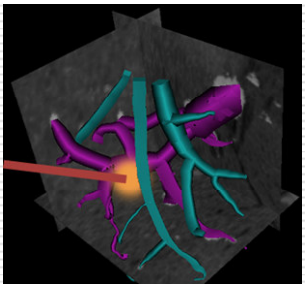
1. Medical Imaging

1.2.The medical view

Medical imaging allows physicians and scientists to glean potentially life-saving information by peering noninvasively into the human body. The role o medical imaging has expanded beyond the simple visualization and inspection of anatomic structures. It has become a tool for surgical planning and simulation, intra-operative navigation, radiotherapy planning and for tracking the progress of disease.

McInerney & Terzopoulos. Deformable Models in Medical Image Analysis: A Survey, *Medical Image Analysis*, 1996



CADDLab, 2006

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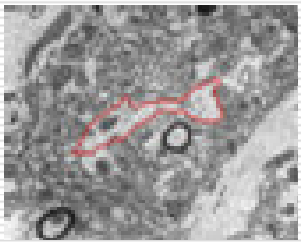
- Current dimensions of medical image applications
- Current trends in medical imaging
- Interactions of medical and biological imagines and techniques



Visual Modeling Showcase Medical Image Analysis

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1.3.Routes of Clinical Applications

- Use of ionized radiation (high energy, short wavelength electromagnetic radiation)
  - **X-ray** (arise from an x-ray tube where high speed electrons bombard a small spot on a tungsten anode target)
  - **gamma rays** (arise from nuclear decays of radioactive tracers introduced into the body)
- Use of non-ionized radiation techniques (Mainly use either acoustic pulses [ultrasound] for echo-ranging imaging, or radio-waves combined with high-field magnets, in the case of magnetic resonance imaging)

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- Medical imaging today drives very fast series of alterations towards the achievement of higher technique sensitivity and specificity, improved resolution and image quality, cellular and molecular level imaging, real time imaging and of course new imaging modalities and storage capabilities.

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2. Clinical Importance

- Help make diagnoses in order to guide therapeutic decisions
- Application in drug and biomarkers discovery, delivery and development
- Image guided therapy (urgery, high-intensity focused ultrasound [HIFU], etc)

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2.1. Decision making

- **Clinical decision making** is the process by which it is determined who needs what and when. While not exactly arbitrary, this exercise can be quite subjective. Each clinician compiles their own data (hence the emphasis on learning to perform an accurate History & Physical Examination) and then constructs an argument for a particular disease state based on their interpretation of the "facts."
- The strength of their case will depend on the way in which medical people gather and assemble information. There may then be no single, right way of applying diagnostic and therapeutic strategies to a particular case. Of course, not every situation is a clinical quandary.

A Practical Guide to Clinical Medicine, *The Regents of the University of California* San Diego, 2005

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- More commonly, however, there exist elements of uncertainty. Medicine involves playing the odds, assessing the relative chance that a patient is/is not suffering from a particular illness.
- Codifying the way in which clinicians logically approach problems and deal with this uncertainty is a difficult task. What follows is my take on diagnostic and therapeutic decision making. It incorporates the following series of questions in a more or less step-wise fashion.

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2.2.Diagnostic & therapeutic decision making

Does this particular clinical situation, on the basis of the H&P, seem familiar (i.e. does it fit any pattern of disease that has been seen/read about)? Is there a single answer which explains even a multitude of complaints/findings? Referred to as Occam's Razor this, in essence, is the search for the simplest possible explanation.

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What other explanations exist? This is known as the "differential." Rather then long, it should be logical. The list is arranged from most to least likely and highlights those conditions that absolutely do not want to miss (i.e. conditions that would result in significant morbidity/mortality if not promptly identified). When searching for explanations, remember that common things occur commonly. While patients do contract unusual illnesses, these are rather rare events.

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Thus, strange symptoms and findings are still more likely to represent an uncommon presentation of a common problem then to be due to an altogether uncommon illness. However, unusual illnesses do occur. Simply has to reassured that is rule out the more run-of-the-mill stuff first!

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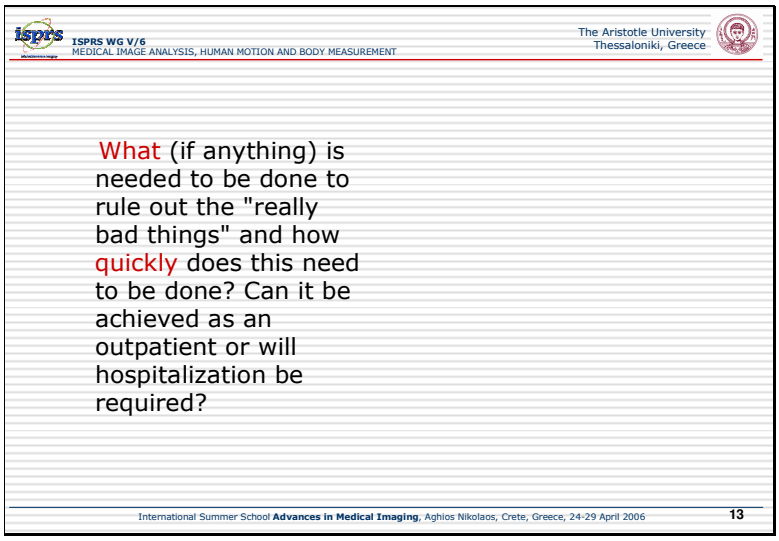
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What (if anything) is needed to be done to rule out the "really bad things" and how quickly does this need to be done? Can it be achieved as an outpatient or will hospitalization be required?
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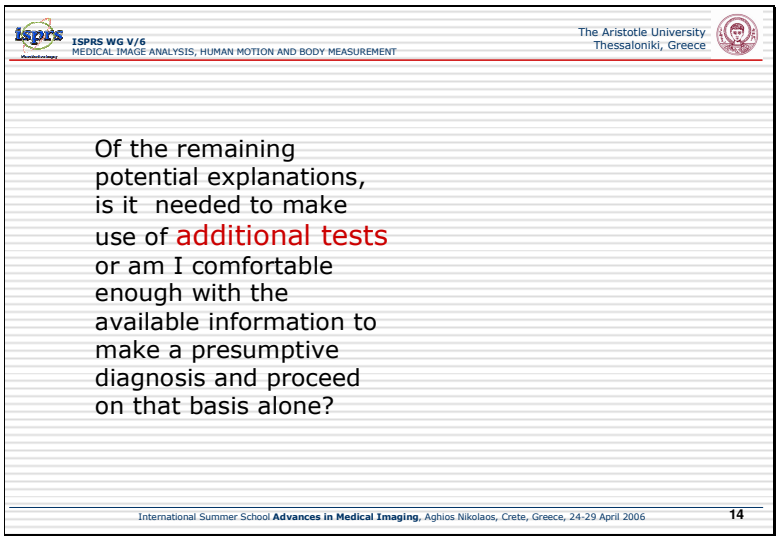
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Of the remaining potential explanations, is it needed to make use of additional tests or am I comfortable enough with the available information to make a presumptive diagnosis and proceed on that basis alone?
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2.3. Ethical consideration

A test should only be obtained if the result will in some way affect the decision making. That is, if you are going to embark on a particular strategy regardless of the results, why obtain it in the first place? Furthermore, if you don't understand the operating characteristics of a test (e.g. it's sensitivity and specificity and thus how the results will affect your view of the candidate diagnosis), it doesn't have to be ordered.

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If the diagnosis is still unclear, can the passage of time be use as a diagnostic test (i.e. perhaps with time the process will more closely resemble a pattern of disease that will be recognizable or simply fade away without explanation)?. However, It may take several observations separated by time before somebody can begin to determine a patient's clinical direction (i.e. getting better, worse or staying the same).

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Does this condition require specific therapy? If so, does It is first needed to have an established diagnosis (see above)? Can the patient wait for this diagnosis to be made before initiating treatment or does their clinical situation mandate the beginning of empirical therapy while a diagnosis is simultaneously being sought?

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Can the treatment be administered as an outpatient or will it require hospitalization (either because of its complexity, compliance issues, patient's compromised clinical condition, need to assess efficacy on a frequent basis, etc.)? What shall be done if the treatment fails to have the desired effect?

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Is the patient on board with this plan? Do they understand the rationale for the approach that has been chosen as well as their role?

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3. Interpretation Issues

- Intelligent interpretation of medical images requires understanding of the interaction of the basic unit of imaging (such as protons in MRI, or X-ray photons in X-ray CT) in a biological environment, formation of a quantifiable signal representing the biological information, detection and acquisition of the signal of interest, and appropriate image reconstruction.
- In brief, intelligent interpretation and analysis of biomedical images require an understanding of the acquisition of images

- Atam Dhawan. 2003 Medical Image Analysis, Wiley-IEEE Press

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3.1. Quality of interpretation

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A conditional matrix for defining four basic performance measures

True Condition

Observed Information

	Object is present	Object is NOT present
Object is observed	**True Positive**	**False Positive**
Object is not observed	**False Negative**	**True Negative**

Atam Dhawan. 2003

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- N_{tot}: Total number of examination cases
- N_{tp}: Cases having positive true-condition with the actual presence of the object
- N_{tn}: Remaining cases having negative true-condition with no object present
- N_{otp} :True Positive: Number of positive observations from Ntp positive true condition cases
- N_{ofn} :False Negative: Number of negative observations from Ntp positive true-condition cases.
- N_{otn} :True Negative: Number of negative observationsfro Ntn negative true-condition cases
- N_{ofp} :False Positive: Number of positive observations from Ntn negative true-condition cases

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$N_{tp}=N_{otp}+N_{ofn}$ and $N_{tn}=N_{ofp}+N_{otn}$

- *True Positive Fraction* (TPF) is the ratio of the number of positive observations to the number of positive true-condition cases

  $$TPF=N_{otp}/N_{tp}$$

- False Negative Fraction (FNF)is the ratio of the number of negative observations to the number of positive true-condition cases

  $$FNF=N_{ofn}/N_{tp}$$

- False Positive Fraction (FPF) is the ratio of the number of positive observations to the number of negative true-condition cases

  $$FPF=N_{ofp}/N_{tn}$$

- True Negative Fraction (TNF) is the ratio of the number of negative observations to the number of negative true-condition cases

  $$TNF=N_{otn}/N_{tn}$$

It should be noted that $TPF+FNF=1$
$TNF+FPF=1$

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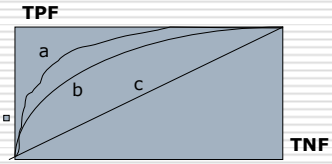
Decision Thresholds based on Receiver Operating Characteristic (ROC) curve



- Sensitivity = **TPF**
- Specificity = **TNF**
- Accuracy = **(TPF+TNF)/N_{tot}**

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- **Sensitivity** = **TPF**

The probability of a test's yielding positive results when a given condition is true

- **Specificity** = **TNF**

The probability of a test's yielding negative results in patients who do not have a disease.

- **Accuracy** = **(TPF+TNF)/N_{tot}**

The ability to measure a quantity with respect to its true value

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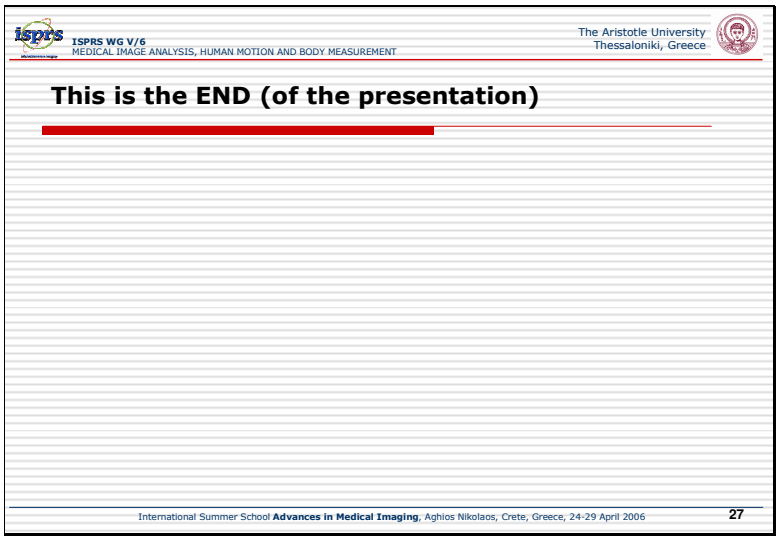
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