C.S. Peirce and the Philosophy of Medical Imaging

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Introduction
Prostate Cancer

- a leading cause of cancer-related death in men
- technology and techniques advancing rapidly
- challenges of communication between physicians, radiologists, surgeons, technicians, and patients
- Peirce’s philosophy illuminates the interpretation of images and the process of diagnosis
Status Quo: Naive Realism

- status quo is unreflective naive realism
  - prostate cancer is a single unchanging thing
  - images mirror reality
  - diagnosis is deduction from image to the thing itself
- ignores and obscures the work done to reconcile conflicting information and changing knowledge
A Pragmaticist Approach

- Peirce’s philosophy is a fruitful alternative
  - prostate cancer understood in terms possible experiments and habits of mind
  - diagnosis involves deduction, induction, and abduction
  - medical imaging as a semiotic process
- practical tools for better communication
- feedback between theory and practice
Prostate Cancer
Past

- Prostate first described 1536, first depicted 1538
- Prostate cancer histology 1853
- First prostatectomy 1904
- Hormone treatments won Nobel Prizes in 1966 and 1977
- Modern therapies started mid-20th century
  - Radium implants
  - Brachytherapy
  - External beam therapy
  - Chemotherapy
Present

- prostate-specific antigen (PSA) measurements
- ultrasound guided biopsy
- radiotherapy
- radical retropubic prostatectomy
- emphasis on sparing nerves and healthy tissue for better quality of life
- smaller tumours detected earlier
- treatment can be postponed in favour of surveillance
Future

- trend toward focal therapy
  - cryotherapy
  - high-frequency ultrasound
  - requires millimetre accuracy
- wider range of imaging options
- other treatments targeting only cancer cells
Continuing Change

“if one can define accurately all of the conceivable experimental phenomena which the affirmation or denial of a concept could imply, one will have therein a complete definition of the concept, and there is absolutely nothing more in it” (‘What Pragmatism Is’ 5.414)

prostate cancer has changed dramatically, and continues to change
Case Study: Multi-Modal Medical Imaging
Image-Guided Prostate Cancer Management

- CIHR Team for Image-Guided Prostate Cancer Management (IGPC)
  - a series of projects to advance prostate cancer treatment
  - funded by Canadian Institutes of Health Research
  - compares ultrasound, MRI, and pathology
  - wide range of techniques, including machine vision

- comparison is difficult
  - the prostate is not rigid
  - imaging, surgery, and pathology change its shape
  - changes in shape are difficult to reconcile across images
Magnetic Resonance Imaging (MRI)

- powerful magnet aligns the spins of hydrogen nuclei (protons)
- a radio pulse flips the spins
- protons “relax” to the previous alignment and emit radio signals
- signals are reconstructed into 2D or 3D images
- differences in relaxation distinguish tissues and structures
- different MRI “sequences” for different uses
T2 Weighted MRI

- primarily distinguishes fat from water
- peripheral zone tumours expected to be hypointense (i.e. darker)
Diffusion Weighted MRI

- measures diffusion of water in tissues
- tumours have higher cell density and are expected to be hyperintense (i.e. brighter)
Apparent Diffusion Coefficient (ADC) MRI

- composite of several diffusion measurements
- tumours expected to be hypointense (i.e. darker)
Contrast MRI

- inject a contrast agent, such as gadolinium, into an artery
- gadolinium-rich blood appears as hyperintense (i.e. brighter)
- images captured in intervals of several seconds over three minutes
- tumours expected to be hypervascular (i.e. more blood vessels)
Early Phase Contrast MRI

- Tumours should show “wash in” (i.e. become brighter) as they take up blood earlier than surrounding tissue.
Late Phase Contrast MRI

- Tumours should show “wash out” (i.e., become darker) as they push out blood earlier than surrounding tissue.
Annotated Whole Mount Pathology

- whole prostate is removed
- treated, stained, fixed in a block of wax, sliced into thin sections, photographed, analyzed
- cancerous cells are distinguished and annotated
Discussion: The Logic of Medical Imaging
Ideal vs. Usual

- these figures are from an ideal case, where signs align
- status quo is to think of diagnosis as deduction from signs to disease
- but signs are usually incomplete or contradictory
Induction

- radiologists have years of training and experience
- from this they induce complex and subtle rules, building habits of mind
- novel cases require new habits
Abduction

- radiologists have to ask “what if?” questions, e.g.:
  - lesion is hypovascular in T2 but not seen in diffusion
  - what if this is tumour that is not hypervascular?
  - deduction: less wash-in and wash-out with contrast
  - induction: use contrast imaging

- reason from a result and a case to a new or modified rule
- the tumour might be different from the ideal
- change habits of mind, require new experiments
Clinician and Community

- clinicians use deduction, induction, and abduction to make diagnoses
- the wider community develops better technologies and techniques
- IGPC as an example:
  - abduction: what if MRI can detect prostate cancer better than ultrasound?
  - deduction: MRI should detect more prostate cancer than ultrasound when both are compared to pathology
  - induction: multi-modal imaging experiments to test the deduction
Praxiography

- Annemarie Mol, *The Body Multiple*
- case study of atherosclerosis (i.e. hardening of the arteries) in the legs
- observed patients, doctors, nurses, technicians, etc.
- points out the diversity of “enactments” by which the disease is experienced
- distribution and coordination of enactments illuminates the work done to bring these experiences together
Semiosis

- medical images and reports are clearly systems of signs
  - diagrammatic reasoning
  - perception and perceptual judgement
  - biosemiotics?
- what can Peirce teach us about this aspect of medical imaging?
- topic of ongoing research . . .
Tools for Clear Communication
Theory and Practise

- virtuous cycle
  - we apply our theoretical understanding to practical applications
  - complexities of practical application drive our theoretical research
- good theory and tools support better abductions, better diagnoses
- practical applications:
  - biomedical ontologies
  - structured reporting
Biomedical Ontologies
Biomedical Ontologies: Terms

- “an ontology” as a carefully constructed system of terminology for a domain
  - Gene Ontology
  - Protein Ontology
  - Foundational Model of Anatomy
  - Common Anatomical Reference Ontology
  - Infectious Disease Ontology
  - Ontology for Biomedical Investigations
  - many more...

- terms have globally unique identifiers
  - example: FMA:9600 “prostate”
    - http://purl.obolibrary.org/obo/FMA_9600

- terms have textual and logical (formal, computable) definitions
- widely used in biomedical informatics
Biomedical Ontologies: Relations and Reasoning

- well-defined logical relations form a network
- examples: “is a” (subtype), “part of”
- computers can follow links to draw inferences
Structured Reporting
Unstructured Reporting: Status Quo

- radiologists use “narrative reports”
  - idiosyncratic terminology and organization
  - very hard to search and analyze
- pathologists tend to use long forms
- we have developed a prototype software tool for structured reporting in prostate cancer
Structured Reporting: Prototype

- diagram, form, and textual report
  - easy to translate into other languages
  - data is easy to search and analyze
- we strive to balance consistency with flexibility
Conclusions
Conclusions

- Peirce’s philosophy is a fruitful alternative to status quo deduction, induction, abduction individual and community reasoning ongoing work on semiosis and perception

- constructive feedback between theory and practise philosophy and medicine

- applications to biomedical ontologies structured reporting