The price of success (greatness) is responsibility.

- Sir Winston Churchill
Diagnostic Imaging

Evolution from ‘deficient’ to ‘essential’

Imaging: Revolutionizing The Practice Of Medicine
MSKCC – CT & PET/CT:
Procedure Volume 1986-2009

MSKCC Department of Radiology Procedure Volume
Moore's law of CT Technology

# of CT slices per second

1 slice in 5 sec

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1 slice in 1 sec

Slice Data acquired each second

- slice in 5 sec
More Slices ≈ More Dose? For like parameters...

CT Chest/Abdomen/Pelvis: 120 kV, 240 mAs, pitch=1, 10 mm, ICRP-60 Wt
L. Dauer, 2009-MSKCC
NCRP Report No. 160, Ionizing Radiation Exposure of the Population of the USA

Collective effective dose (person-Sv)
- Early 1980's: 835,000
- 2006: 1,870,000

Effective dose per individual in the U.S. population (mSv)
- Early 1980's: 3.6
- 2006: 6.2

Pie chart showing:
- Background: 85%
- Consumer: 15%
- Occupational Industrial: 15%
- Medical: 0%
- Occupational: 0.1%
- Consumer 2%
Separate the Wheat from the Chaff
Diagnostic Imaging
Revolutionizing The Practice Of Medicine

- Changing Practice Paradigms
  - Exploratory Laparotomy

Virtual Laparotomy by Imaging
Contrast Enhanced CT
Diagnostic Imaging
Revolutionizing The Practice Of Medicine

• Changing Practice Paradigms
  • Exploratory Laparotomy
  • Staging Laparotomy
    e.g. Lymphoma

Staging by Imaging
Diagnostic Imaging

Revolutionizing The Practice Of Medicine

- Changing Practice Paradigms
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Staging by Imaging
Diagnostic Imaging
Revolutionizing The Practice Of Medicine

• Changing Practice Paradigms
  • Exploratory Laparotomy
  • Staging Laparotomy  
    e.g. Lymphoma
  • Treatment Selection
    • Surgery

MR Hysteroscopy
Surgery or Radiation Therapy
Diagnostic Imaging

Revolutionizing The Practice Of Medicine

• Changing Practice Paradigms
  • Exploratory Laparotomy
  • Staging Laparotomy e.g. Lymphoma
• Treatment Selection
  • Surgery
  • Radiation Therapy
  • Image Guided Intervention

IMRT or IGRT are Image Based

1250
Prostate Cancer MRI/MRSI

9895
Image Guided Intervention
Hybrid Equipment; Robotics; Navigation Software; Smart Catheters

Angio-CT Room
Image Guided Intervention

Hybrid Equipment; Robotics; Navigation Software; Smart Catheters

CT Robotics – Biopsy

MRI Navigation Guided Biopsy
Oncologic Imaging
Personalized - Evidence Based Medicine

- Changing Practice Paradigms
  - Exploratory Laparotomy
  - Staging Laparotomy e.g. Lymphoma
  - Treatment Selection
    - Surgery
    - Radiation Therapy
    - IGI
  - Treatment Follow-up

Monitoring Tumor Response: modern technology

Percentage Change in the measurement

- 3.4%
- 40.7%

3 month follow-up: Diameter=17.1 mm
Volume=886 mm³
Volume=525 mm³
Lung Cancer
Anatomy & Metabolism in Cancer Management

CT

Computer Modeling
Tumor Volume

$^{18}$FDG PET

$^{18}$FDG PET/CT
Tumor Glycolysis ~ SUV
Aggregate Imaging Growth Was The Fastest For Physician Services: 1999-2004

Aggregate Growth in Medicare Services per Beneficiary (1999-2004)

- Imaging = 2X

31% growth for all physician services

*Courtesy: J Thrall*
Overutilization of Imaging

Application of an imaging procedure under circumstances where it is unlikely to improve patient outcome
Observations

- Overutilization & Inappropriate use of imaging is unquestionably present
- Total overutilization is difficult to measure
- Overutilization is highly variable between different settings

Overutilization in Imaging is **OUR** problem

- Referring Physician
- Radiologists
- Technologists
- Medical Physics/Radiation Protection
- Industry
- Health System
- Patients
Observations

- **Referring Physicians**
  - Lack of knowledge on part of referring physicians—10-15%* (e.g. ER, Ca Follow-up)
  - Defensive medicine (pt preferences) – 5-25%*
  - Self-referral– 8%-12%*
  - Practice variation
  - Lack of systems for decision support/utilization management
  - Lack of evidence based guidelines (cancer follow-up)

*Courtesy: J Thrall
For head MRI and CT, up to 20% of patients at MGH have had prior exams.

Dotted Line~% of ROE events that resulted in a scheduled examination

- Green: No dup fire > scheduled
- Orange: Dup fire > scheduled
- Light Green: No dup fire > not scheduled
- Beige: Dup fire > not scheduled

*Courtesy: J Thrall*
Cancer Imaging in Clinical Trials & Clinical Practice

- For most Cancers there are no evidence based imaging guidelines (reimage in 3m, 4m, 6m)
- Practice variation
- Patient demands
- Defensive Medicine
Observations

- **Radiologists**
  - Recommendations for additional imaging
    - Confidence/experience/defensive medicine
  - Lack of awareness/knowledge about radiation exposure when designing new protocols
    - Is thinner section needed?
    - Do multiple passes offer incremental information?
  - Practice variations: Culture/Habits and not evidence driven
  - Failure/inability to review appropriat. of ordered exams
  - “Over marketing” for marginal indications
  - Lack of confidence or experience
  - Practice culture/self referral

- **Technologist**
  - Education in radiation protection for patients and themselves
Interventional Radiology

Staff Concerns?

- Cataract risk appears to be higher than once thought (ICRP).
- Staff doses directly related to Patient skin doses.
- Efforts to protect patient also protect staff!
- More important as we transition to increased IR in OR for image guided interventions.

Dauer et al. MSKCC - 2009
Moving Forward

Radiologists/Technologist/Physicists

Image Gently
Society for Pediatric Radiologist, ACR, AAPM, ASRT

Image Wisely
RSNA, ACR, AAPM, ASRT
Observations

- **Industry**
  - Standardization
    - Variations in reported dose for exactly the same protocols is not acceptable
  - Agreement on which dose needs to be reported
  - Radiation dose should automatically become a part of radiology reports and EMR

- **Health system factors**
  - Failure to eliminate financially motivated self-referral
  - Failure to control number of imaging devices
Patient Factors/Patient Request

- Patient Factors:
  - Lack of knowledge of what imaging can and cannot do
  - Expectation that imaging will be performed from prior health care encounters
  - Preference to understand source of symptoms—especially MSK
  - Demands/expects imaging procedure
  - Weekend warrior syndrome
  - Too little financial responsibility—no deductible or co-pay
  - Family/friends advice
Five Technologies Set to Change the Decade* (2009 - 2019)

- Building-Integrated Photovoltaics (BIPV)
  - (solar technology projected to generate 50% of the electrical needs of the developing countries)
- Personal Genome Sequencing
- Molecular Imaging
- Graphene Transistors
  - (nanomaterial graphene to replace silicon flash memory chips)
- Multi-touch Displays

Self-sufficiency in growth signals

Insensitivity to sub-growth signals

Tissue invasion & metastasis

Limitless replicative potential

Evading apoptosis

DNA Replication/Cell Proliferation: $^{18}$F-FLT PET/CT

Single Dose IGRT

Hanahan D; Weinberg RA: Cell 2000

Six Hallmarks of Cancer

7/25: before RT SUV 19.5

08/01: one day after RT SUV 12.5

08/22: 21 day after RT SUV 2.4

DNA Replication/Cell Proliferation: $^{18}$F-FLT PET/CT

Single Dose IGRT

Hanahan D; Weinberg RA: Cell 2000
The Essence of Personalized Medicine

Biomarkers: Serum, Tissue or Imaging

• Predictive Biomarkers
  • Selecting specific therapy: identify relative sensitivity or resistance to specific treatments or agents
  • “Prognosis determinants” identify early stage cancers in NO need of aggressive therapy (e.g. prostate cancer)

• Early Response Biomarkers

• Prognostic Biomarkers
  • Informs about an outcome independent of specific treatment
Targeted Imaging in Breast Cancer Metastasis
Predictive Biomarker & Learning about Tumor

Precision Medicine

Tumor Metastasis - De-differentiates (30-50%)

Predictive Biomarkers for Tumor Metastasis

$^{18}$FDG PET/CT

Investigational: NM Service - MSKCC

$^{64}$Cu Trastuzumab PET/CT
Prostate Cancer: Imaging Tumor Biology

Heterogeneous Biology of Tumor Metastasis

Investigational: NM Service - MSKCC
Separate the Wheat from the Chaff

The price of success (greatness) is responsibility.

- Sir Winston Churchill

- Responsibility
- Accountability
- Knowledge
- Industry standards
- Evidence Based Guidelines

$^{18}$FDG PET/CT
Lung Cancer
Theranostics: Targeted Imaging & Targeted Therapy

January 2008

CT

February 2008

18FDHT PET/CT showing AR treatment response

Therapy © Androgen Receptor Inhibitor: Investigational: NM Service - MSKCC
Predictive Biomarkers in Tumor Response

Breast Cancer: HER2 expression phenotype and genotype

HER2 Negative Immunophenotype

HER2 Normal Gene Copy

HER2 Positive Immunophenotype

HER2 Amplified Gene Copies

Tumor Metastasis - De-differentiates (30-50%)

Predictive Biomarkers for Tumor Metastasis
Predictive Biomarkers in Tumor Response
Breast Ca-HER2 Theranostics: Targeted Imaging/Targeted Therapy

- e.g. Tracers for PET/CT targeted imaging for HER2
  - $^{64}$Cu Trastuzumab
  - $^{68}$Ga-(Fab’2) Herceptin

$^{64}$Cu Trastuzumab PET/CT

$^{68}$Ga-(Fab’2) Herceptin PET/CT

Investigational: NM Service - MSKCC
Interventional Radiology

Skin Dose Concern?
- FDA warnings on patient injury potential.
- Joint Commission Sentinel Event (>15 Gy).
- Equipment Enhancements helping to increase image quality while reducing dose.
- Training, training, training
- Other Organ Dose Concerns? (little data)

Figure 1. Histogram of estimated PSD for 3,945 instances of various interventional radiology procedures for oncology patients during 2006.

Lymphoma

$^{18}$FDG-PET in Treatment Design and Follow-up

$^{18}$FDG PET/CT: Pre-therapy $^{18}$FDG PET/CT: Post-therapy
**Imaging Hypoxia - $^{18}$FMISO PET/CT**

Identifying a radioresistant tumor sub-population

**Hypoxia - distribution**

**Hypoxia - tumor size**

$^{18}$FMISO PET/CT

$^{18}$FMISO PET

$^{18}$FMISO PET
Is Imaging Being Over Utilized?

- Imaging services and costs have clearly grown disproportionately to overall health care costs this decade.
- Growth per se has been taken as evidence of “overutilization”.
- Clearly growth is not the same as overutilization.
- However, detail level considerations support the conclusion that overutilization exists and that numerous factors are driving it.
Duplicate Exams: Duplicate exams = unnecessary repeat exams of same or similar nature
Difficult to determine in many settings
  - Fragmented care process
  - Imperfect patient memory
  - Lack of electronic records
  - Lack of diligence by referring provider

• Referring Physician Factors
• Lack of knowledge about the patient/Failure to adequately examine
  • Duplicate exams/orders
  • Lack of knowledge of when to use imaging or apply appropriateness criteria
  • Practice variation between providers
Inappropriate Financially Motivated Self-referral

Financial motivation versus medical necessity

Appropriateness criteria not used/ignored
Defensive Medicine

The application of diagnostic or therapeutic measures primarily as a safeguard against possible malpractice liability and not to ensure the health of the patient.
The Number of Imaging Exams Per Medicare Enrollee Increased Disproportionately To Other Services: 1999-2004

**Figure 1. Growth in the Volume of Physician Services per Beneficiary, 1999–2004.**
Volume is measured as units of service multiplied by each service’s relative value units from the physician fee schedule. Analysis includes claims for 100 percent of Medicare beneficiaries for all 12 months of each year. Evaluation and management service includes office visits and hospital visits. The category “Tests” excludes imaging.
Duplicate Exams: Duplicate exams= unnecessary repeat exams of same or similar nature
Difficult to determine in many settings
  - Fragmented care process
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• Referring Physician Factors

• Lack of knowledge about the patient/Failure to adequately examine

• Duplicate exams/orders

• Lack of knowledge of when to use imaging or apply appropriateness criteria

• Practice variation between providers
Lung Tumor: CT Screening?

CT Follow-up with Computer Modeling

Baseline

Measurements
Max. dia = 4.5 mm
Perpendicular = 2.4 mm
Area = 8.4 mm²
Volume = 24.1 mm³

3 Month Follow-up

Measurements
Max. dia = 5.8 mm
Perpendicular = 3.5 mm
Area = 16.4 mm²
Volume = 53.9 mm³
Moore's law of CT Technology

# of CT slices per second

1 slice in 1 sec

1 slice in 5 sec

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Slice Data acquired each second

Moore's law of CT Technology
Lung Cancer Diagnostics

PET/CT

Virtual Bronchoscopy
Dr. Mayer-Hermann - Otto Dix (German, 1891-1969)