# Innovations in medical imaging: research in academics and industry

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## Acknowledgements

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- GE Healthcare
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- Samsung Electronics

## Outline

Impact of medical imaging (medical, economic)

Progress through innovation in diagnostic imaging

Vignettes during my time in industry

Vignettes from academia

Conclusions

## Economic impact

| annual worldwide market | 2014 | |
|---|---|---|
| CT | $4B | |
| MRI | $5.5B | |
| PET & SPECT | $9.5B | |
| Ultrasound | $6B | |
| TOTAL | $27B | |

Sources: BBC Research, MarketsandMarkets, Medical News Today, Transparency Market Research

## Economic impact

| annual worldwide market | 2014 | 1974 |
|---|---|---|
| CT | $4B | ~0 |
| MRI | $5.5B | ~0 |
| PET & SPECT | $9.5B | ~0 |
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| TOTAL | $27B | ~0 |

Sources: BBC Research, MarketsandMarkets, Medical News Today, Transparency Market Research

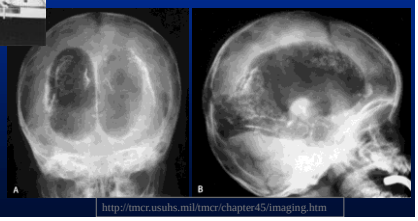
## Economic impact

- ~75M CT and ~35M MRI procedures/yr in USA
- Medical imaging is ~$100B per year (US)
- Lots of people employed
- Many patients are impacted

Sources: Healthday, Organization for Economic Co-operation and Development

## Medical impact


Pnumoencephalography
no longer used




(**A**) AP and (**B**) lateral pneumoencephalography of patient with congenital toxoplasmosis with hyrocephalus.

http://tmcr.usuhs.mil/tmcr/chapter45/imaging.htm

## Medical impact

modern imaging replaced most of exploratory surgery

## Medical impact

patient with
meningioma

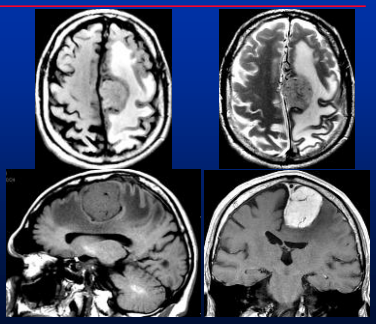


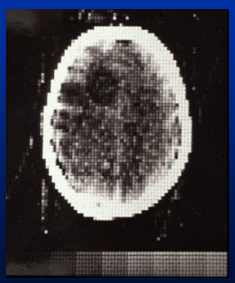
**EXHIBIT 3**
**Mean Response And Ranking Of Physicians' Ratings Of Innovations, 2001**

| Rank | Innovation | Mean score[a] | Percent of respondents choosing: Most | Not most or least | Least |
|---|---|---|---|---|---|
| 1 | MRI and CT scanning | 0.878 | 75.6% | 24.4% | 0.0% |
| 2 | ACE inhibitors | 0.767 | 54.2 | 44.9 | 0.9 |
| 3 | Balloon angioplasty | 0.758 | 53.8 | 44.0 | 2.2 |
| 4 | Statins | 0.736 | 48.0 | 51.1 | 0.9 |
| 5 | Mammography | 0.733 | 47.6 | 51.6 | 0.9 |
| 6 | CABG | 0.693 | 40.4 | 57.8 | 1.8 |
| 7 | Proton pump inhibitors and H2 blockers | 0.687 | 40.0 | 57.3 | 2.7 |
| 8 | SSRIs and recent non-SSRI antidepressants | 0.678 | 39.6 | 56.4 | 4.0 |
| 9 | Cataract extraction and lens implant | 0.651 | 38.2 | 53.8 | 8.0 |
| 10 | Hip and knee replacement | 0.649 | 31.6 | 66.7 | 1.8 |
| 11 | Ultrasonography | 0.647 | 31.1 | 67.1 | 1.8 |
| 12 | Gastrointestinal endoscopy | 0.624 | 28.0 | 68.9 | 3.1 |
| 13 | Inhaled steroids for asthma | 0.591 | 23.6 | 71.1 | 5.3 |
| 14 | Laparoscopic surgery | 0.558 | 20.9 | 69.8 | 9.3 |
| 15 | NSAIDs and Cox-2 inhibitors | 0.531 | 14.2 | 77.8 | 8.0 |
| 16 | Cardiac enzymes | 0.498 | 7.1 | 85.3 | 7.6 |
| 17 | Fluoroquinolones | 0.487 | 6.7 | 84.0 | 9.3 |
| 18 | Recent hypoglycemic agents | 0.478 | 12.9 | 69.8 | 17.3 |
| 19 | HIV testing and treatment | 0.444 | 15.6 | 57.8 | 26.7 |
| 20 | Tamoxifen | 0.440 | 3.1 | 81.8 | 15.1 |
| 21 | PSA testing | 0.438 | 12.9 | 61.8 | 25.3 |
| 22 | Long-acting and parenteral opioids | 0.376 | 8.4 | 58.2 | 33.3 |
| 23 | H. Pylori testing and treatment | 0.351 | 1.8 | 66.7 | 31.6 |
| 24 | Bone densitometry | 0.344 | 4.0 | 60.9 | 35.1 |
| 25 | Third-generation cephalosporins | 0.329 | 1.8 | 62.2 | 36.0 |
| 26 | Calcium channel blockers | 0.291 | 1.8 | 54.7 | 43.6 |
| 27 | IV-conscious sedation | 0.289 | 1.8 | 54.2 | 44.0 |
| 28 | Sildenafil (Viagra) | 0.256 | 0.9 | 49.3 | 49.8 |
| 29 | Nonsedating antihistamines | 0.231 | 1.3 | 43.6 | 55.1 |
| 30 | Bone marrow transplant | 0.182 | 1.3 | 33.8 | 64.9 |
| | All 30 innovations | 0.520 | 22.3 | 59.6 | 18.2 |

## How do innovations have impact?

- Publications and dissemination can alter research, and clinical use if changes don't require system mods or approvals
- Broad impact of technological changes requires commercialization

## Progress through innovation



EMI Mark I
1973

# Progress through innovation

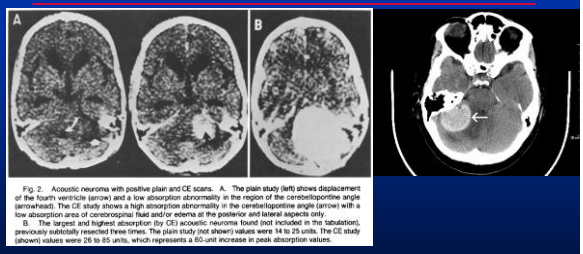


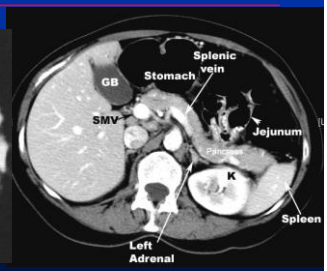

Fig. 2. Acoustic neuroma with positive plain and CE scans. A. The plain study (left) shows displacement of the fourth ventricle (arrow) and a low absorption abnormality in the region of the cerebellopontine angle (arrowhead). The CE study shows a high absorption abnormality in the cerebellopontine angle (arrow) with a low absorption area of cerebrospinal fluid and/or edema at the posterior and lateral aspects only.
B. The largest and highest absorption (by CE) acoustic neuroma found (not included in the tabulation), previously subtotally resected three times. The plain study (not shown) values were 14 to 25 units. The CE study (shown) values were 26 to 85 units, which represents a 60-unit increase in peak absorption values.



Radiology 124:81-86, 1977

http://education.vrad.com

# Progress through innovation

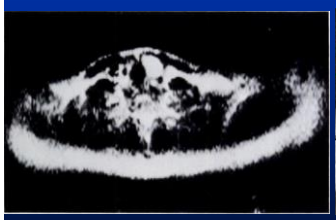


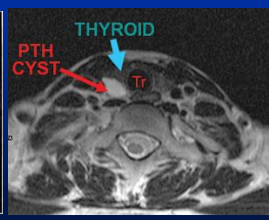

1976

now

http://ctprotocol.blogspot.com

# Progress through innovation






1983

now

RadioGraphics 4:5-25, 1984

http://ctprotocol.blogspot.com

## Progress through innovation

Completely new product:
commercialization is often by a new company

Improvement to existing product:
commercialization is usually through existing company

## Outline

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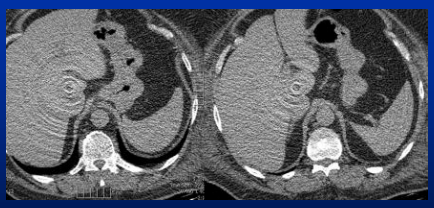
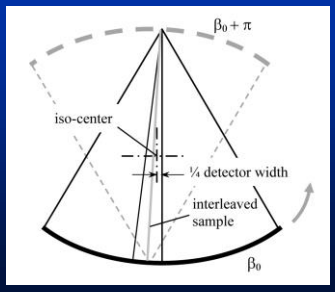
## Improved calibration methods



new methods improved reliability and image quality
and reduced manufacturing and service cost

http://emedicine.medscape.com/article/383412-overview

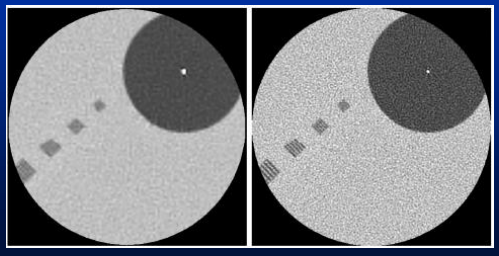
# Quarter-detector offset




Hsieh, "Computed Tomography Principles, Design, Artifacts, and Recent Advances", 2009.

# "Bone-detail" reconstruction

"standard" "bone detail"



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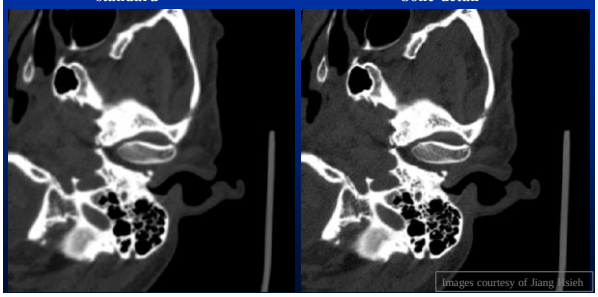


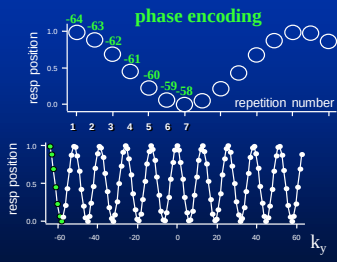
Images courtesy of Jiang Hsieh

## Observations

- Problems were important to the business
- There was an in-house expert and advocate (me)
- Relatively easy implementation
- Incorporated into the product quickly
- Innovations helped the customers and the company

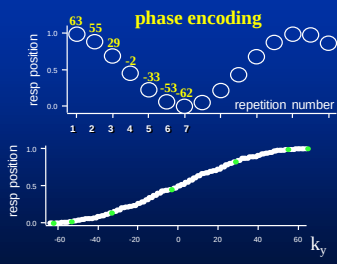
## Respiration artifacts in MRI

Conventional Acquisition



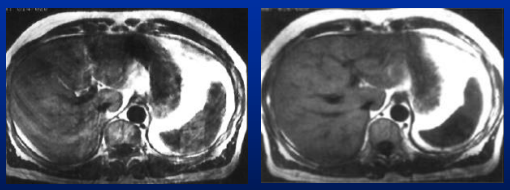

Result => ghosting

## Respiratory Compensation




Result => reduced ghosting

## Respiration artifacts in MRI



Conventional Acquisition

Respiratory Compensation

## Observations

- Feature was important to the business
- There was an in-house expert and advocate (me)
- Complicated implementation: hardware, operator interface, scan software, pulse sequences, reconstruction, operator interface
- Incorporated into the product

## Cardiac pulsation artifacts

Zhu J, Gullapalli RP. "AAPM/RSNA Physics Tutorial for Residents: MR Artifacts, Safety, and Quality Control." RadioGraphics 2006; 26:275–297.

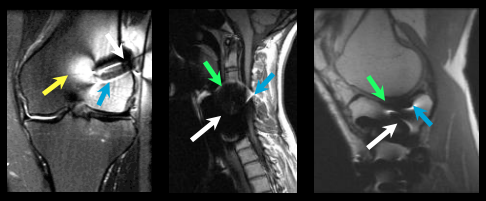
- Potential solution: phase encoding order based on cardiac cycle
- Relatively simple adaptation of resp comp feature already in the product
- Stanford clinicians liked it
- Not incorporated in the product

# Observations

- Moderately easy implementation
- Not incorporated into the product
- Lack of perceived market impact?
- No in-house expert/advocate?
- Needed resources were required elsewhere?

## MRI near metal

Four common metal artifacts are shown…



Signal Loss

Failed Fat Suppression

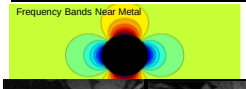
Distortion / Displacement

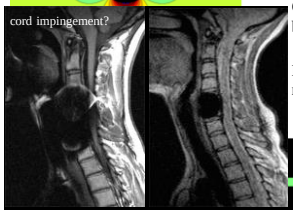
Hyperintense signal "pile-up"

Often occur together, from multiple mechanisms

courtesy of Brian Hargeaves, PhD

## SEMAC




512x192, 3 NEX, 3mm
T;W Spin Echo (5min)

256x192, 60% $k_y$, 4mm
PD SEMAC (11 min)

Slice Encoding for Metal Artifact Correction

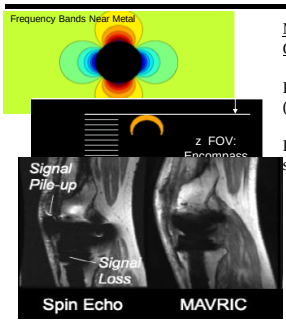
Combination of techniques - longer scan time but more robust in the presence of metal

Developed at Stanford but GE was informed regularly

*Lu, et al. MRM 2009*

courtesy of Brian Hargeaves, PhD

## MAVRIC




Multiacquisition Variable-resonance Image Combination

Developed independently by a scientist at GE (Kevin Koch)

Different combination of techniques, not slice selective

*Koch, et al. MRM 2009*



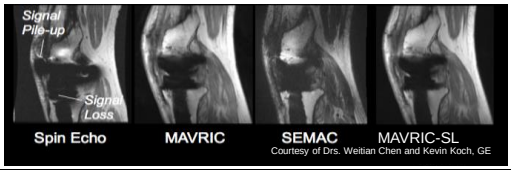
## MAVRIC-SL

Kevin Koch and Brian Hargreaves knew and understood each other's techniques. Wide and open communications

SEMAC and MAVRIC have different strengths and weaknesses. One is superior in some cases; the other is others

A "hybrid of the two was created and implemented in GE product (MAVRIC-SL)

Methods published and licensed. Similar techniques implemented by other vendors






## Observations

- Moderately complicated implementation
- Feature was important to customers
- There was an in-house expert and advocate
- Incorporated into the product
- Communication between the academic and industry groups, before and after commercialization decision, was critically important

## Summary

- Medical imaging innovations have had a huge impact, clinically and economically. Medical physicists contributed greatly
- Impact of innovations needs dissemination.
- Commercialization makes innovations widely available to the medical community and public

## Summary

- Physicists within companies play a great role
  - innovators
  - experts and advocates for innovations
    - internal innovations (including their own)
    - external advances
- Physicists in the community and academia are closer to the clinician and clinical needs

## Dissemination decisions

- Commercialization decisions are complex
  - Assessment of commercial opportunity
  - Needed resources? Are they available?
- Within companies: internal matter. Physicists should be engaged.

## Dissemination decisions

- Commercialization/dissemination of academic innovations can be by several routes:
  - Place it in the public domain
  - Patent and license. Expectations must be realistic.
  - Starting a new company may be appropriate for completely new product
  - Working with existing company may be more effective for evolutionary advances

## Academic - industry partnership

- "Evolutionary" advances accumulate to huge impact
- Collaboration and communication between academia and industry is essential
- New compliance policies and expectations of both sides can be a barrier
- Don't throw out the baby with the bathwater

Thank You