Digital Pathology: Past, Present and Future

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Pathologist
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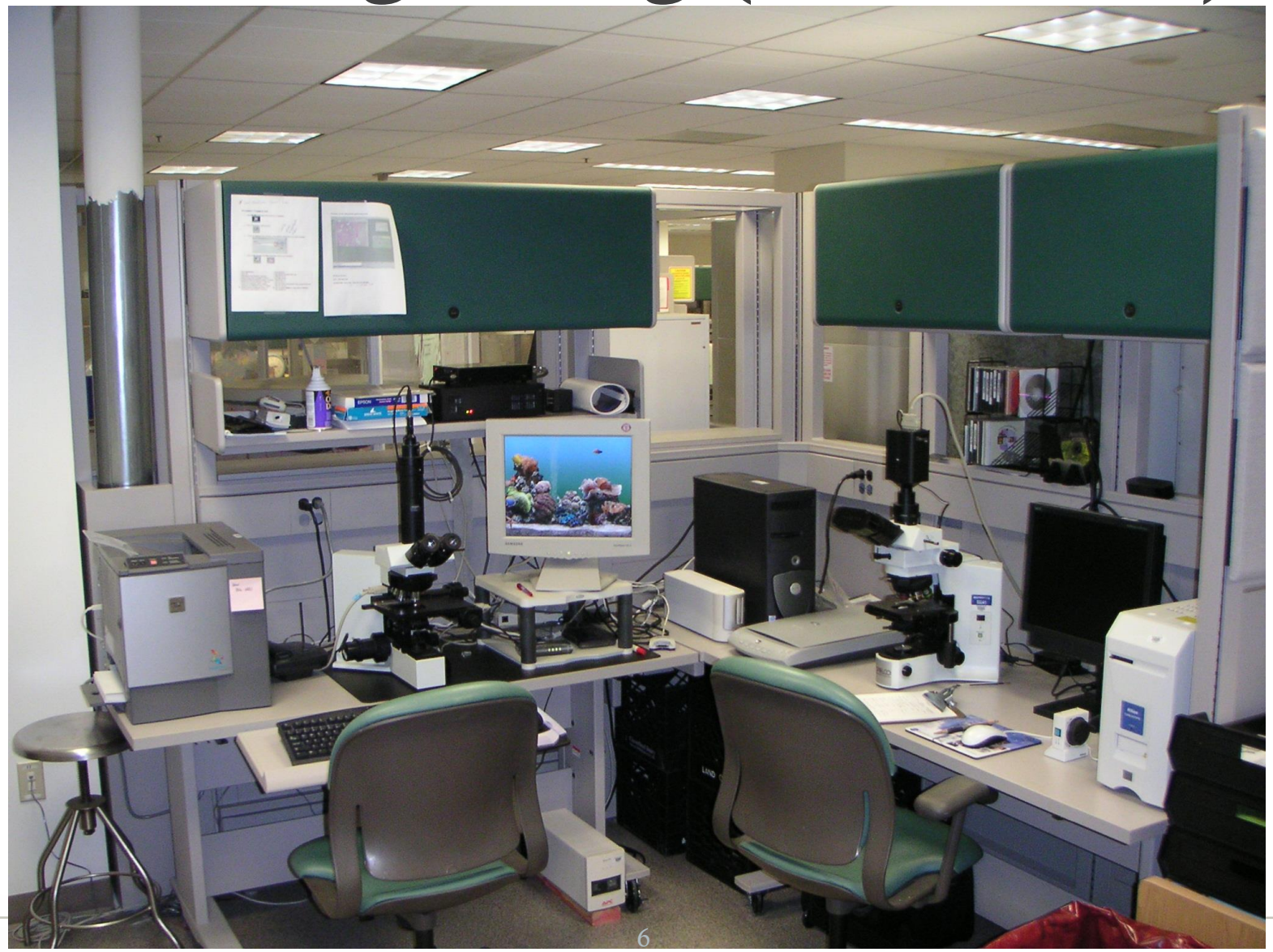
“You can observe a lot by just watching.”


TAKE
LOSER

In the beginning (circa 2000)

In the beginning (circa 2001)



In the beginning (circa 2002)

Use of Robotic Telepathology for Frozen-Section Diagnosis: A Retrospective Trial of a Telepathology System for Intraoperative Consultation

Keith J. Kaplan, M.D., Jeanette R. Burgess, M.D., Glenn D. Sandberg, M.D., Cris P. Myers, M.D., Thomas R. Bigott, B.S., Renata B. Greenspan, M.D.

Department of Pathology (KJK, JRB, RBG) and Telemedicine Directorate (TRB), Walter Reed Army Medical Center, Washington, DC; Department of Neuropathology, Armed Forces Institute of Pathology (GDS), Washington, DC; and Department of Pathology, Heidelberg Army Hospital (CPM), Heidelberg, Germany

Telepathology is the practice of digitizing histological or macroscopic images for transmission along telecommunication pathways for diagnosis, consultation, or continuing medical education. Previous studies have addressed static *versus* dynamic imaging in several specimen types with a wide variety of systems and communication pathways. The goal of

KEY WORDS: AFIP, Diagnosis, Frozen section, Telepathology.

Mod Pathol 2002;15(11):1197–1204

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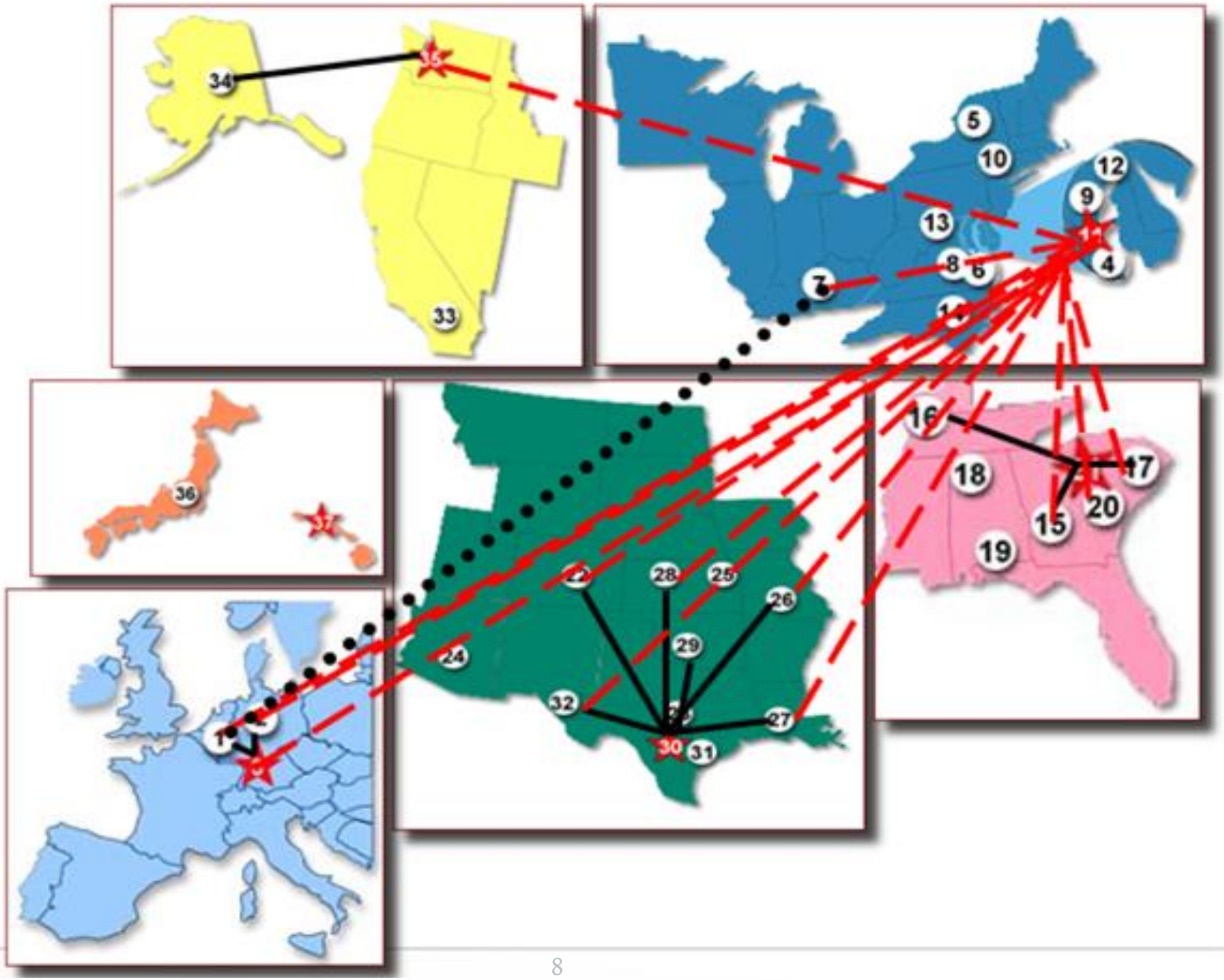
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Army Telemedicine Program

- Walter Reed AMC (6/01)
- WRAMC CBCP (6/01)
- Ft. Knox (IACH) (8/01)
- Ft. Bragg (WAMC) (11/01)
- Landstuhl RMC (12/01)
- Tripler AMC (4/02)
- Heidelberg AH (1/03)
- Wuerzberg AH (1/03)
- Ft. Benning (MACH) (1/03)
- Ft. Hood (DACH) (2/03)
- Brooke AMC (2/03)
- Korea (EACH) (2/03)
- Ft. Riley (IACH) (10/03)
- Ft. Sill (RACH) (10/03)
- Ft. Carson (EACH) (2/04)
- Eisenhower AMC (3/04)
- Ft. Campbell (BACH) (3/04)
- Ft. Jackson (MACH) (3/04)
- Ft. Stewart (WACH) (3/04)
- Ft. Leonard Wood (GLWACH) (3/04)
- Iraq (31st CSH) (11/04)
- Ft. Eustis (MACH) (5/05)
- Air Force Academy (5/05)
- Ft. Belvoir (DACH) (9/05)
- Madigan AMC (10/05)

In the beginning (circa 2003)

The Next Best Thing To Being There

And Now, Diagnosis by Satellite

The patient, a 66-year-old woman with cancer in her left breast, lay in a hospital in El Paso, Tex. The doctor about to make her diagnosis was nearly 2,000 miles away in Southwest Washington.

Sitting at a computer terminal in the Comsat building in L'Enfant Plaza last Wednesday, Dr. Alexander Miller, an expert in gynecological pathology, studied a televised image of a biopsy, a microscopic sample of tissue taken from the patient's breast. He quickly determined that the tumor had spread throughout the breast and that more surgery was necessary.

"You can have a piece of tissue under a microscope in Texas and an image in Washington so clear that you see the microscopic detail . . . well enough to make an immediate diagnosis."

Colburn, D 1986, 'The next best thing to being there', *The Washington Post,* 27 Aug, p. H7

Television Aids In Operation

By FRANK CAREY
Associated Press Science Reporter

WASHINGTON, Jan. 19 (AP) — In history's first test of its kind, two doctors in different cities concurred via color television today in diagnosing a breast cancer in a woman.

As the patient, identified only as "a lovely 46-year-old woman," lay anesthetized on an operating table in Philadelphia, a pathologist there microscopically examined a piece of test tissue removed from her right breast.

Then, as doctors in Philadelphia, Washington and Baltimore watched and heard him over a three-way closed TV circuit, he gave his definite opinion that the tissue was cancerous. But he asked the view of a pathologist watching the whole thing from Baltimore.

The latter, without hesitation, also voiced his opinion the tissue was cancerous—and then the surgeons in Philadelphia went ahead with the operation, although this was not seen on TV.

The televised preliminaries to the operation were all part of a symposium sponsored by the Armed Forces Institute of Pathology and centered in Washington. The symposium is designed to explore possible new uses of color television in medicine.

Pathologists in Washington who witnessed the demonstration generally agreed that at the present stage of development of color TV, doctors at widely separated points could consult via TV on a diagnosis, as was done in the test.

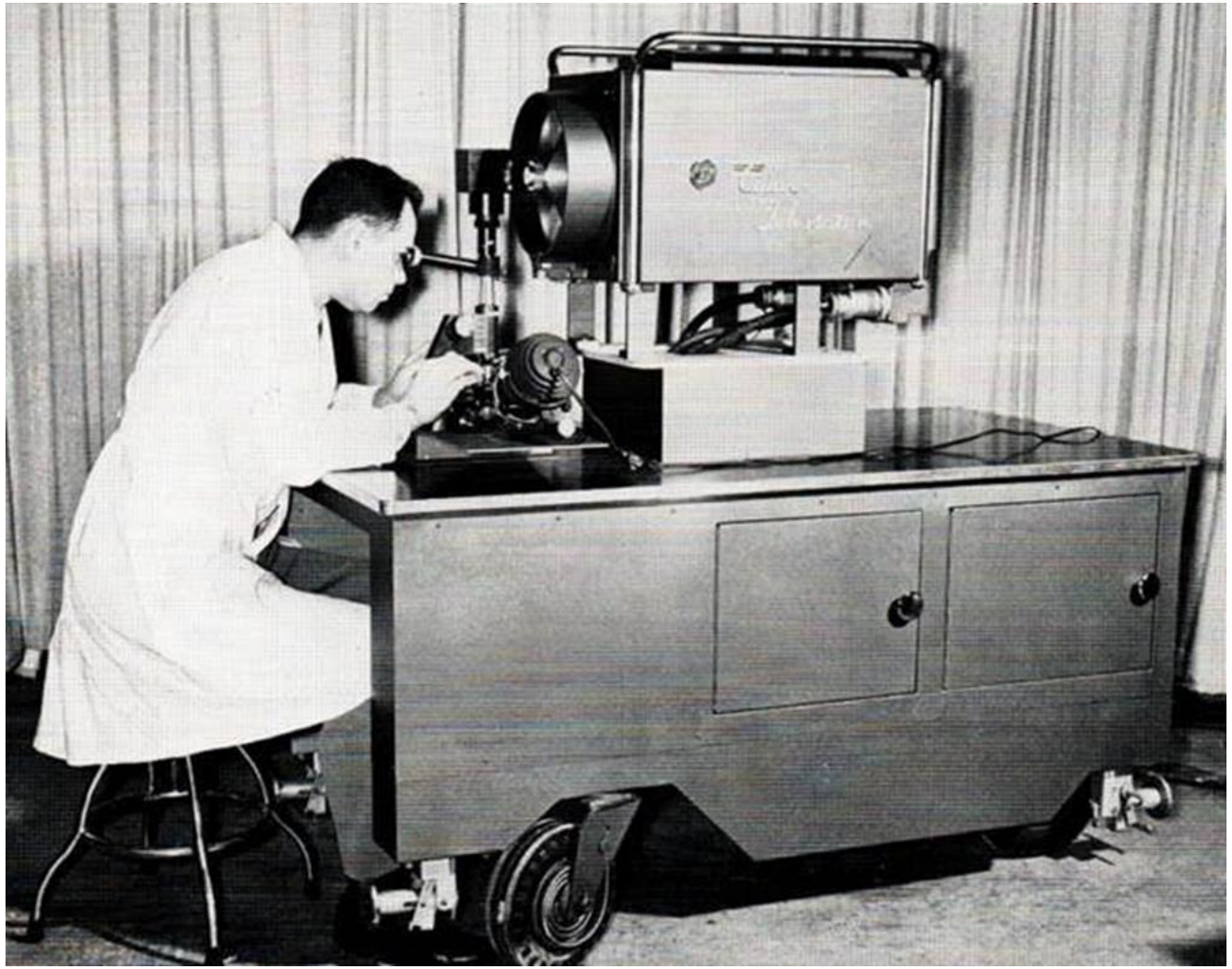
But they also agreed that the day is not yet here when a pathologist at a remote point could make the decision alone, without consultation with a pathologist attending the patient.

Scientists say that tas remoe diagnosis would be an invaluable aid o hospitals and communities lacking full pathological facilities.

Bing Crosby Undergoes Successful Operation

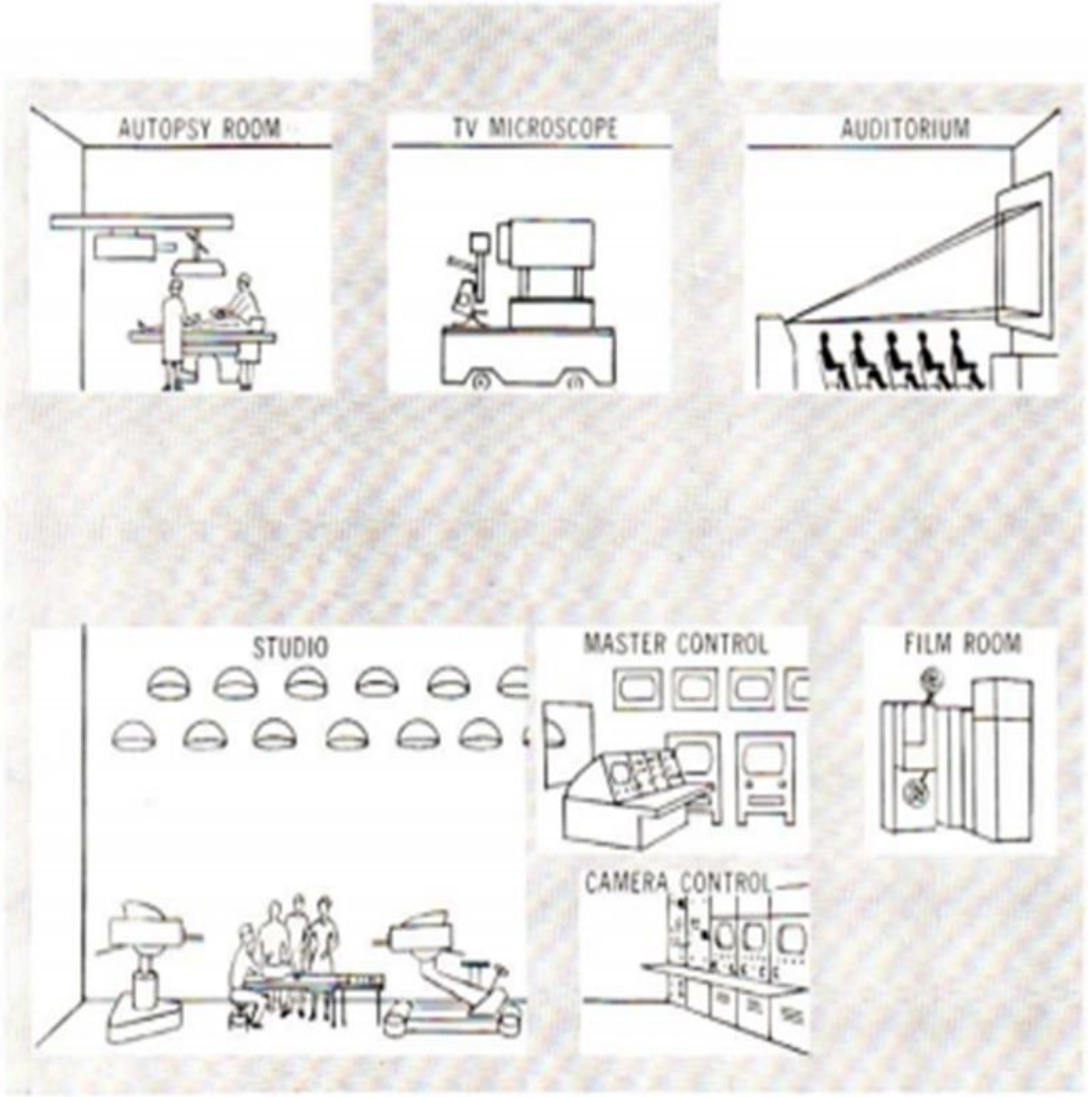
SANTA MONICA, Calif., Jan. 19 (AP)—Bing Crosby, 50, had a kidney stone removed today and he came through the operation in "excellent condition."

The crooner was in the surgery ward at St. John's Hospital four hours and under surgery for two hours and 15 minutes. Dr. Frederick C. Schulmberger told reporters he removed a stone and per-



AFIP Archives 1/19/1955 courtesy of Toby Cornish MD

ARMED FORCES INSTITUTE OF PATHOLOGY



WALTER REED ARMY HOSPITAL

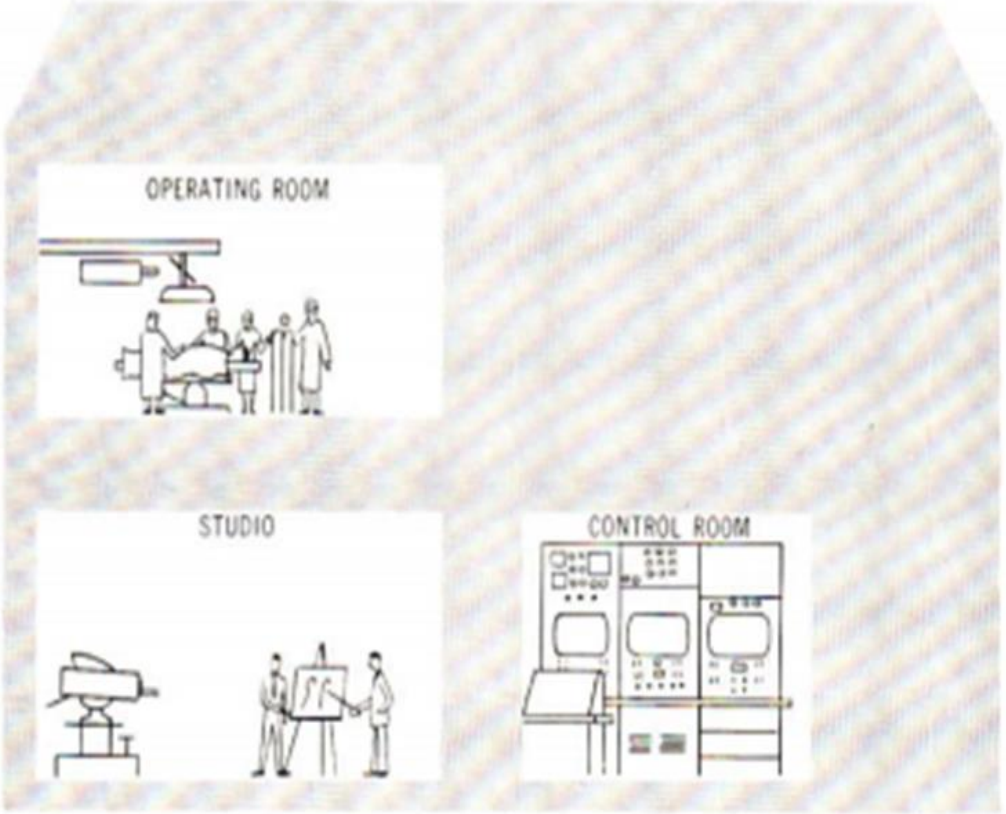


FIG. 4. These drawings show the three independent Color TV systems in the Walter Reed Army Medical Center—


DELL


LEWIS
U.S.ARMY

AFIP DEPARTMENT OF TELEMEDICINE

CASE TRACKING SHEET

PATIENT'S NAME (Last, First, M.I.) _____

2855613-00

2855613 - 00

025-60-3680

Walter Reed Army Medical Center 60

S02-16306 TELEPATHOLOGY 12/6/2002

Y1 Turner, Diane

Case Processing Steps

Date and Time:

Fax Received 12-6-2002 0935

Image Received 12-6 2002 0935

Case Accessioned 0935 **Picked Up** 1000

Pathology Branch Review 1045

Report Typed for Signature 1200

Report Faxed to Contributor 1245

Case Finalized 1245

Finalize Code 3

Entered into Database 1300

Report scanned and archived _____

Image Format: TRESTLE

Image Resolution TRESTLE

Transmission Format SS

Comments:

DEPARTMENT OF DEFENSE
ARMED FORCES INSTITUTE OF PATHOLOGY
WASHINGTON, DC 20306–6000

REPLY TO ATTENTION OF

PATIENT IDENTIFICATION
AFIP ACCESSION NO. SEQUENCE NO.

[redacted]

January 16, 2003

[redacted]
Heidelberg MEDDAC
CMR 442
Box 512
APO AE 09042

TELEPATHOLOGY REPORT

AFIP REPORT [redacted] Right breast, biopsy: Moderately differentiated (Grade II) infiltrating ductal carcinoma.
: Ductal intraepithelial neoplasia, grade 2 (DIN 2 = DCIS, grade 2), solid and cribriform types with necrosis.

Thank you for sharing this case in telepathology consultation. The slide selected for review shows an infiltrating ductal carcinoma that is moderately differentiated based on Nottingham grade (T=3,N=2,M=1; score 6 of 9). As you have indicated, an associated DIN 2 (DCIS, grade 2) is present. The intraductal component comprises approximately 20-25% of the selected slide. Definitive lymph-vascular invasion is not identified, however, the assessment of lymph-vascular invasion, tumor size, and margin status are deferred to the contributing pathologist.

Number of Images
1 TrestleCorp

CPT: 88321

Image quality is good.
A copy of this report has been faxed to you at DSN 314 371 2015.
This report is not valid until countersigned by the originating pathologist.

[redacted]
MAJ, MC, USA
Staff Pathologist
Department of Gynecologic and Breast Pathology

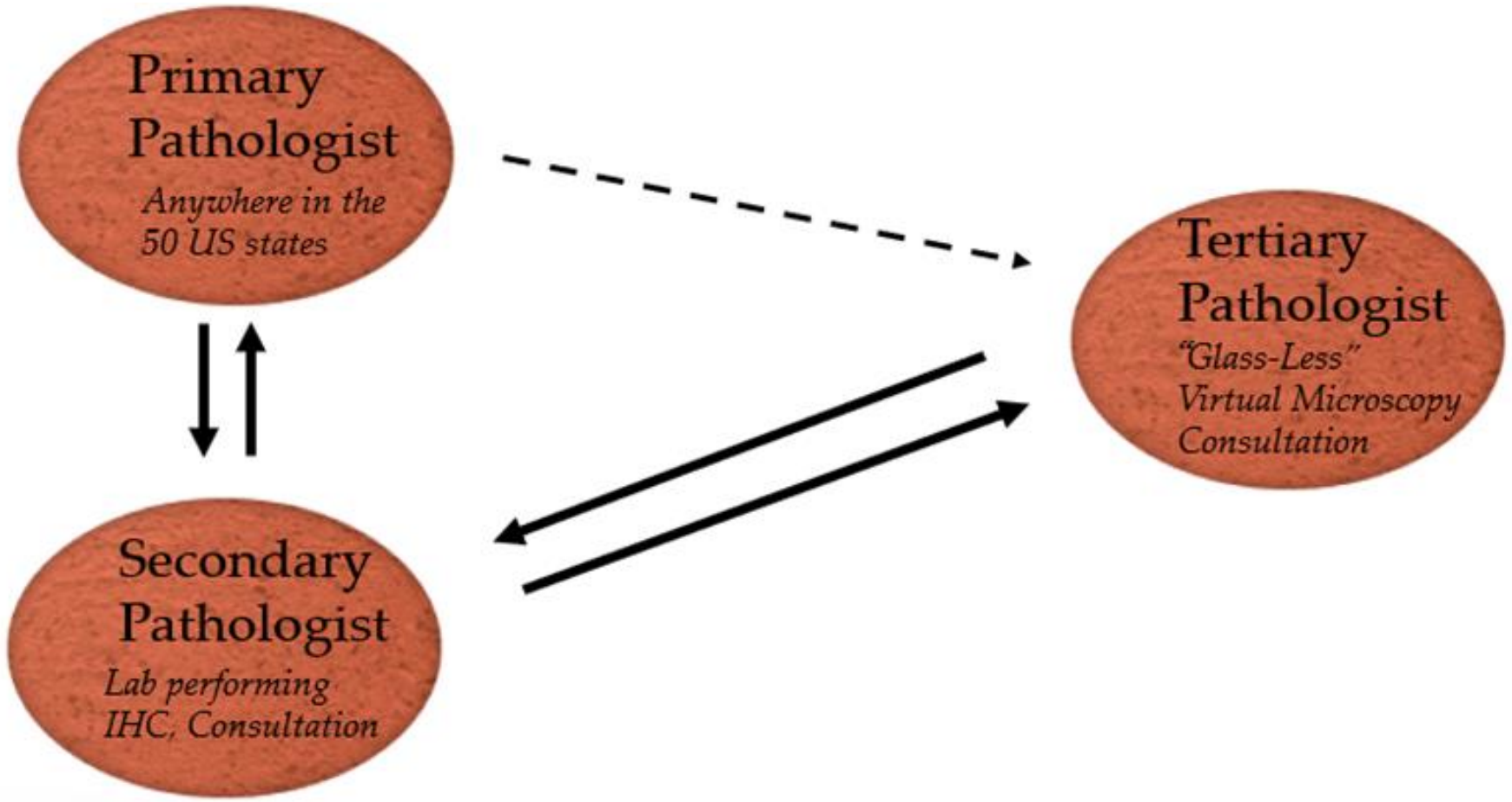
Originating Pathologist
[redacted]
Heidelberg MEDDAC
CMR 442
Box 512
APO AE 09042

Department of Telemedicine
6825 16th St., N.W., Bldg 54 Room 3001, Washington D.C. 20306-6000
Telephone: (202) 782-2883/2884; Fax: (202) 782-9010

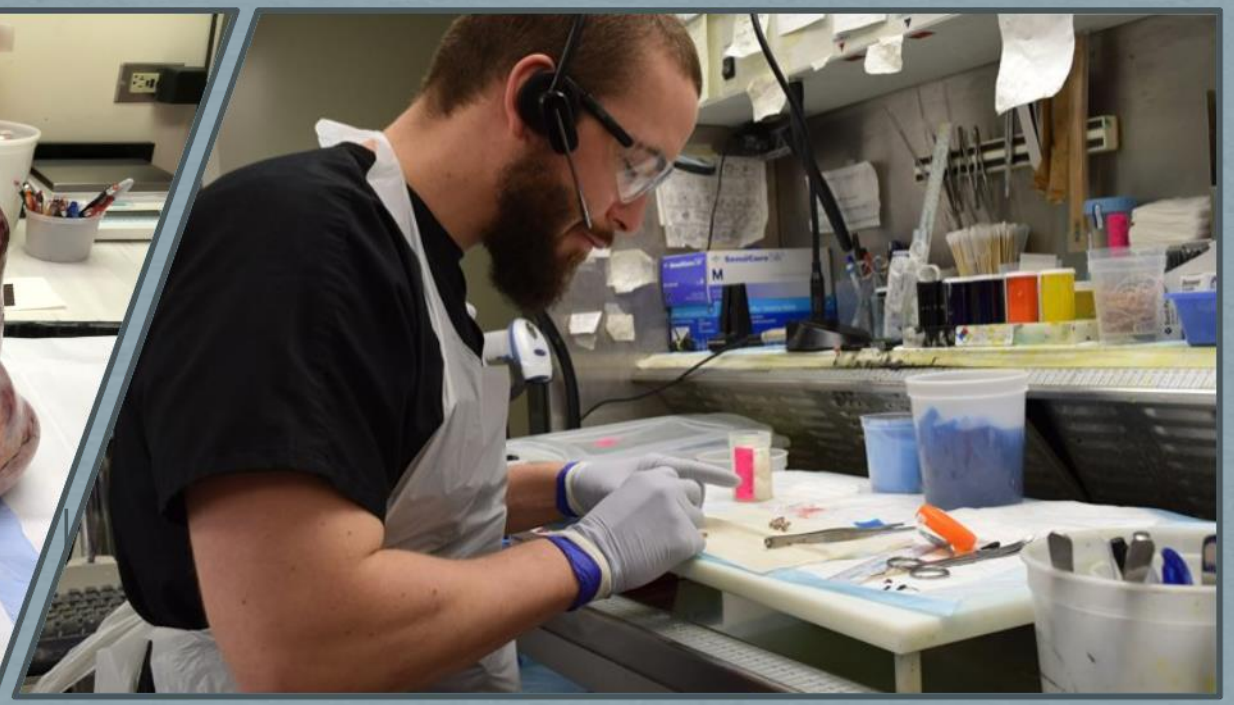
Value Propositions

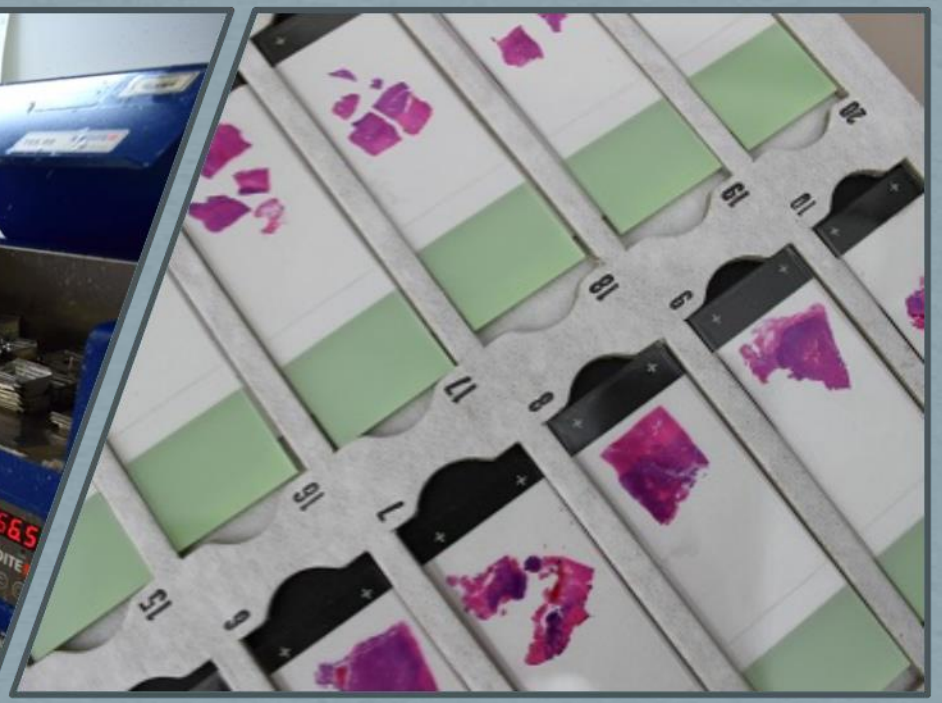
- Tele-pathology; Remote read, consult, review, quality assurance, peer review; slide and reader at some distance for information to flow
- Distance from slide/laboratory
- Image Analysis (Deep learning/AI)
- Content Based Image Retrieval (CBIR); Query by Image Content (QBIC) and Content-Based Visual Information Retrieval (CBVIR)
  - Application of computer vision techniques to image retrieval problem of searching for digital images in large databases; Searching images with images

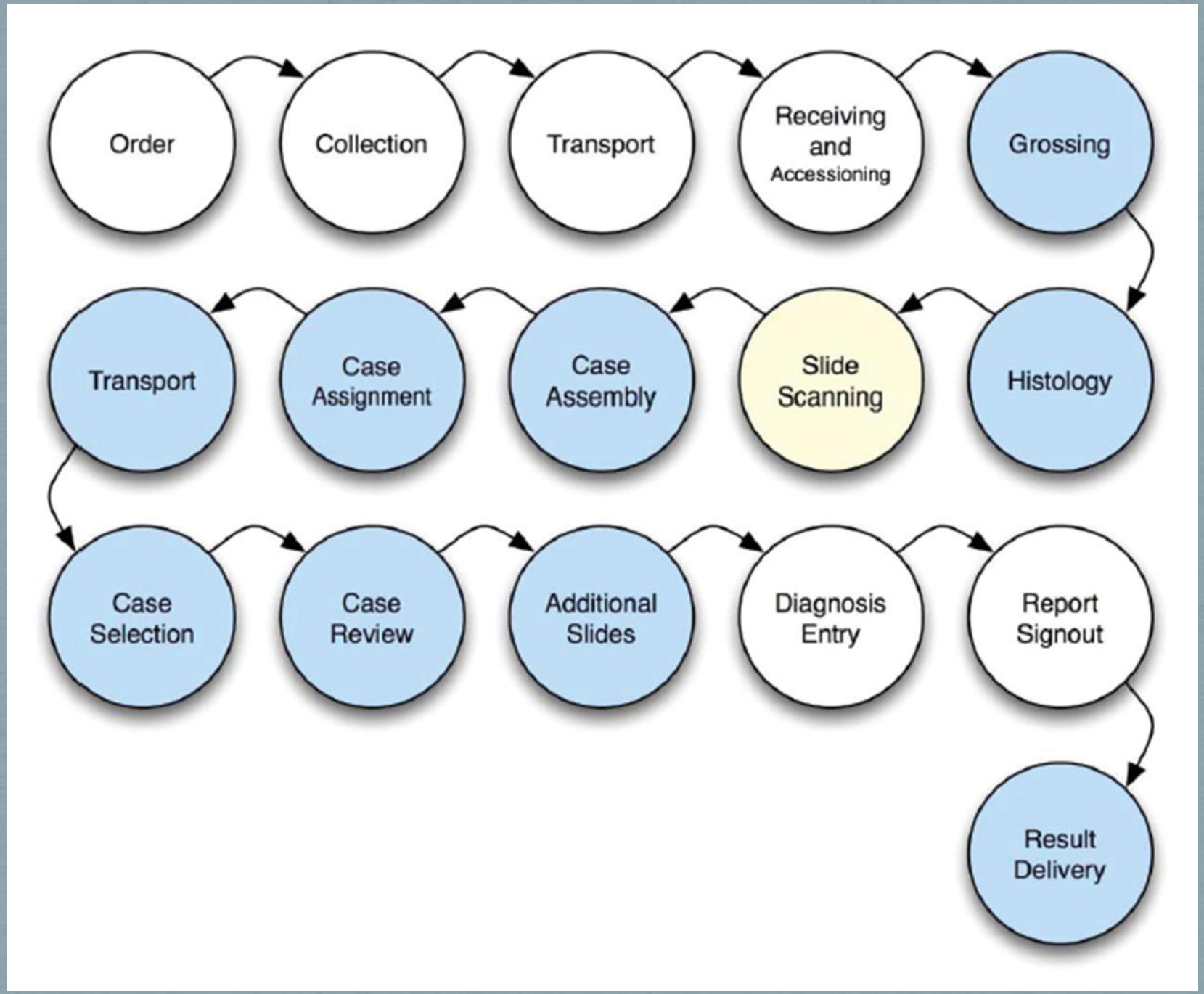
Circa 2007


Primary Pathologist
Anywhere in the 50 US states
Tertiary Pathologist
"Glass-Less" Virtual Microscopy Consultation
Secondary Pathologist
Lab performing IHC, Consultation


VWR






Order
Collection
Transport
Receiving and Accessioning
Grossing
Transport
Case Assignment
Case Assembly
Slide Scanning
Histology
Case Selection
Case Review
Additional Slides
Diagnosis Entry
Report Signout
Result Delivery

Differentiated Service Model

- Shared expertise/coverage/collaboration
- Improved consultation and turnaround time
- Elimination of slide shipping & handling issues
- Connectivity to patients/colleagues/clients/hospitals
- Image analysis applications
- Extensive/searchable image results database

“The future ain’t what it used to be.”

Role of pathologists - historical

- The "Doctor's Doctor"
- Provide anatomic and clinical pathology consultations to other physicians
- Growth of commercial labs, subspecialty labs and consolidated healthcare systems with core labs
- Increases distance between pathologist and patient
- Loss of status, stature & recognition of valued member of healthcare team

Role of pathologists - today

- "The Patient's Doctor"

- Uniquely positioned at root of treatment decisions being diagnosticians and gatekeepers of appropriate laboratory tests

- Strong patient advocates – i.e. image guided fine-needle aspirations, tissue conservation, molecular diagnostics, triage & correlation with synoptic reporting

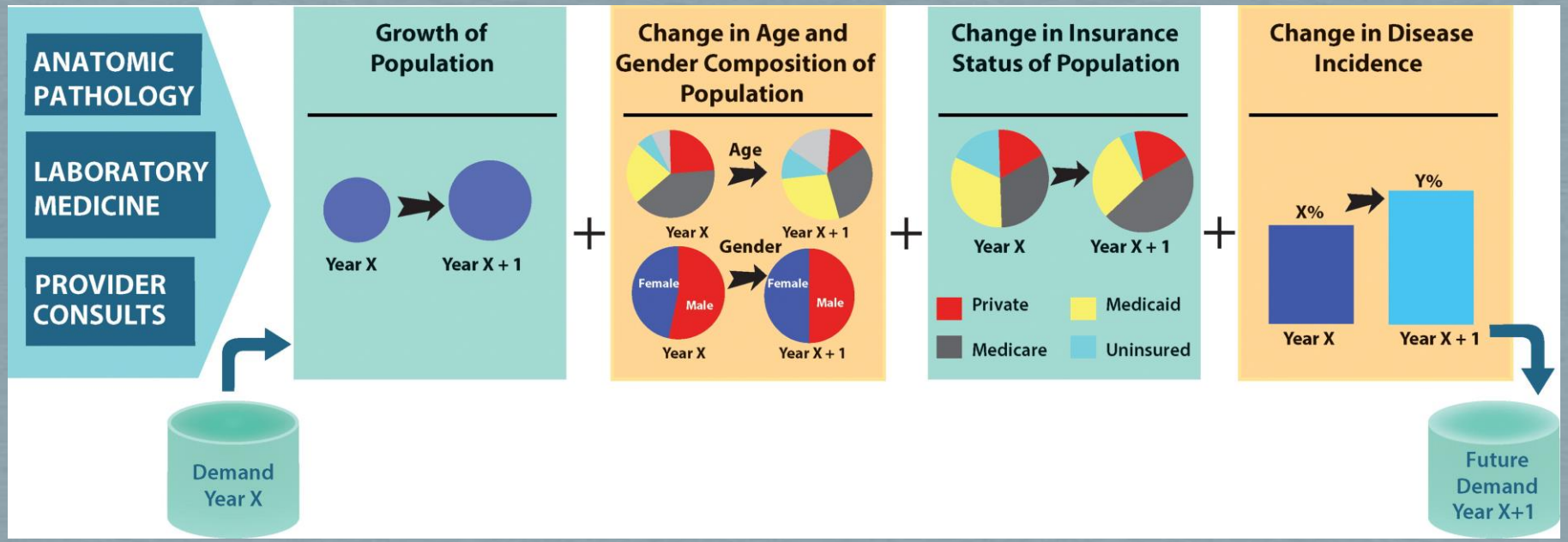
Current practice climate

- Fragmented
- Communication and IT issues even within “integrated healthcare delivery systems”
- Local vs. Regional vs. National referral centers – referrals based on relationships
- Declining reimbursements/uncertainty/fear in marketplace – challenge to innovate/workflow modifications
- Little direct patient contact based on geography, practice or geopolitical/business forces

Current practice opportunity

- Importance of pathology valued by patients and their families
- Re-establish status in medicine and healthcare delivery systems
- Use technologies that facilitate information transfer
- Provide direct correlation with pathology and patient questions
- Integrate within clinical workflows to facilitate appropriate therapies and decision making

~~Predicted~~ Pathologist Shortage



VIEWPOINT

INNOVATIONS IN HEALTH CARE DELIVERY

Adapting to Artificial Intelligence
Radiologists and Pathologists as Information Specialists

Saurabh Jha, MBBS, MRCS, MS
Department of Radiology, University of Pennsylvania, Philadelphia.

Eric J. Topol, MD
Scripps Research Institute, La Jolla, California.

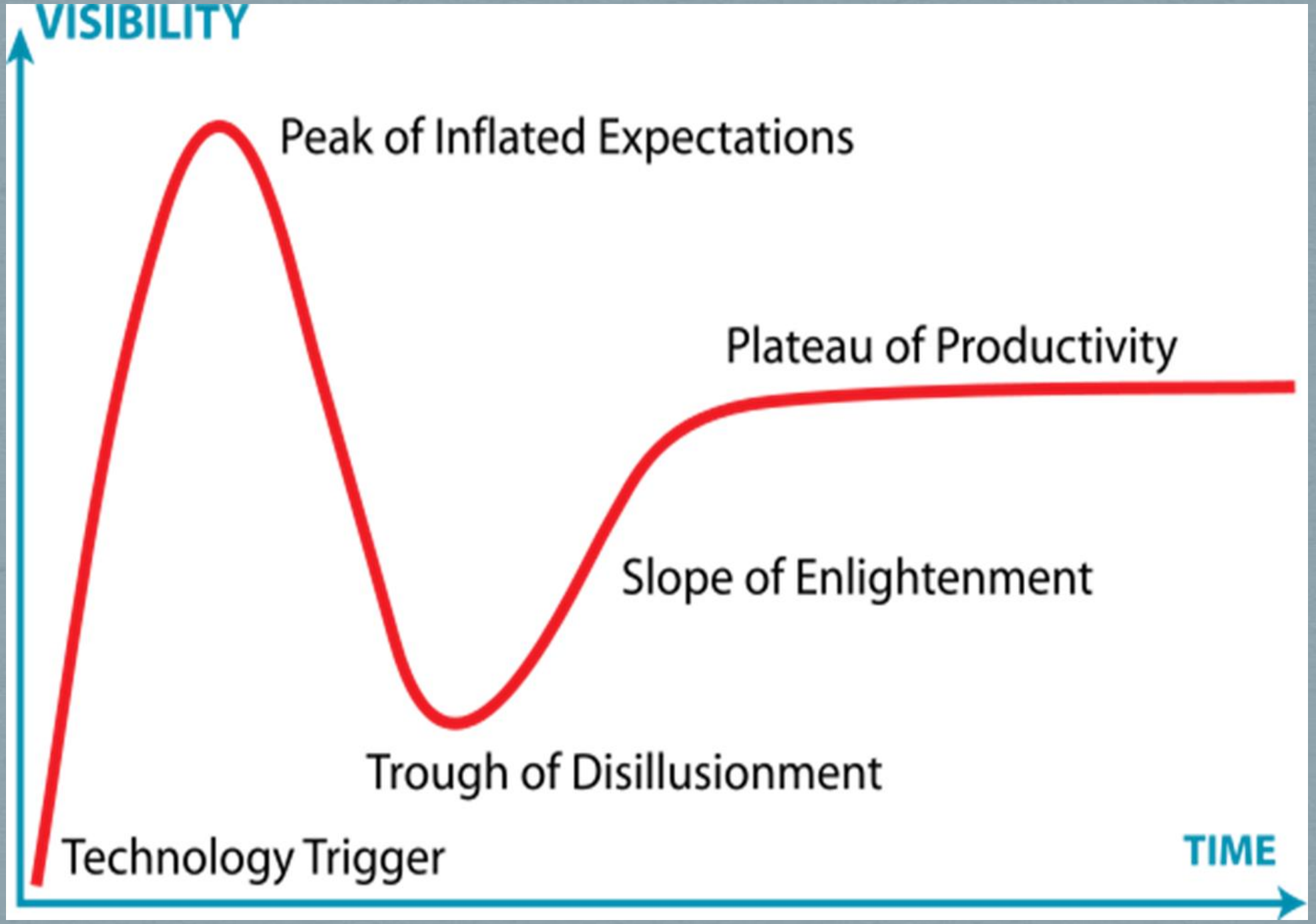
Editorial

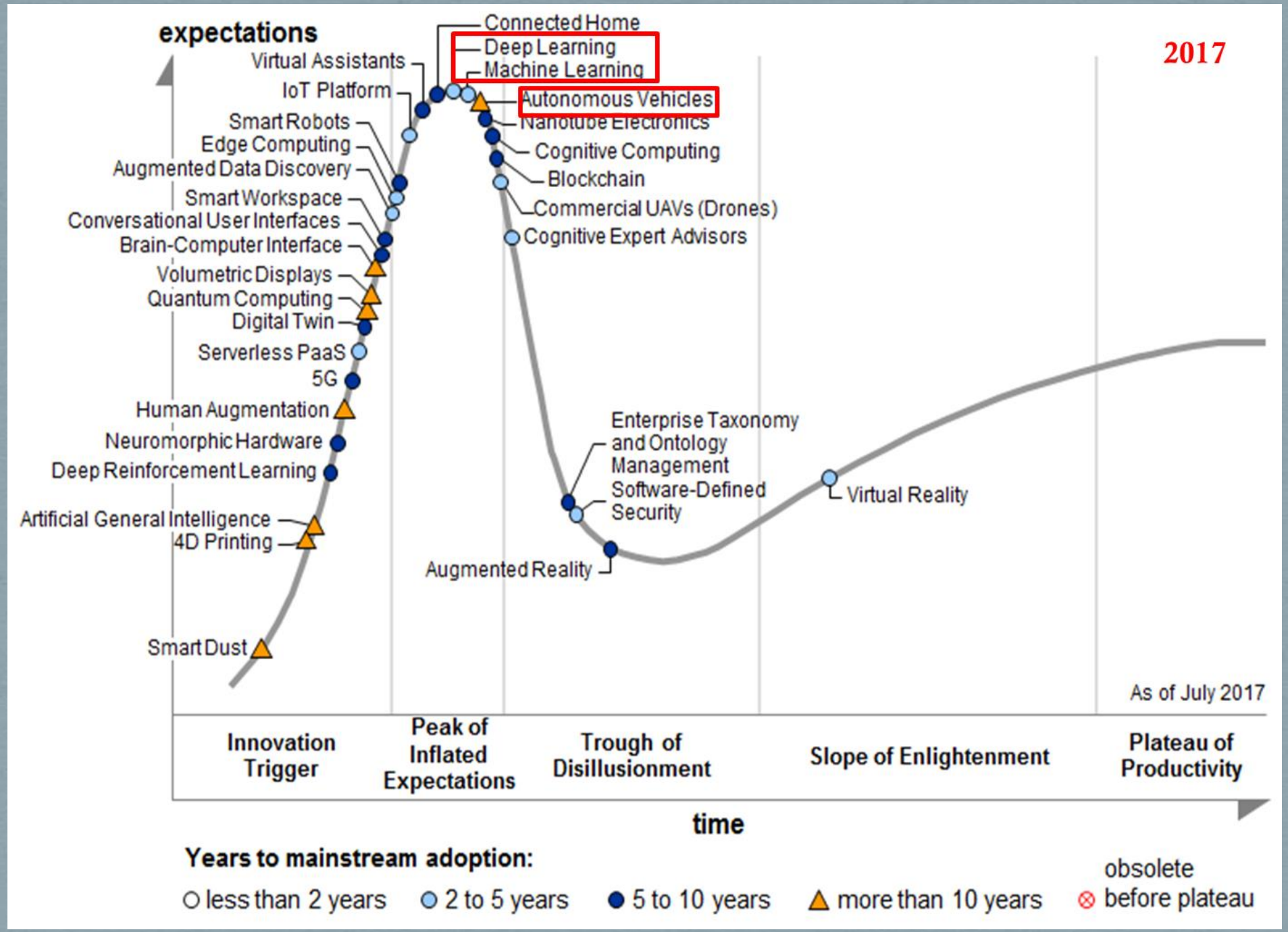
Artificial intelligence—the mimicking of human cognition by computers—was once a fable in science fiction but is becoming reality in medicine. The combination of big data and artificial intelligence, referred to by some as the fourth industrial revolution,[1] will change radiology and pathology along with other medical specialties. Although reports of radiologists and pathologists being replaced by computers seem exaggerated,[2] these specialties must plan strategically for a future in which artificial intelligence is part of the health care workforce.

Radiologists have always revered machines and technology. In 1960, Lusted predicted "an electronic scanner-computer to examine chest photofluorograms, to separate the clearly normal chest films from the abnormal chest films."[3] Lusted further suggested that "the abnormal chest films would be marked for later study by the radiologists."[3] Lusted's intuitions were prescient: interpreting radiographs is pattern recognition; computers can

This progress in imaging has changed the work of radiologists. Radiology, once confined to projectional images, such as chest radiographs, has become more complex and data rich. Cross-sectional imaging such as CT and magnetic resonance, by showing anatomy with greater clarity, has made diagnosis simpler in many instances; for example, a ruptured aneurysm is inferred on a chest radiograph but actually seen on CT. However, this has come at a price—the amount of data has increased markedly. For example, a radiologist typically views 4000 images in a CT scan of multiple body parts ("pan scan") in patients with multiple trauma. The abundance of data has changed how radiologists interpret images; from pattern recognition, with clinical context, to searching for needles in haystacks; from inference to detection. The radiologist, once a maestro with a chest radiograph, is now often visually fatigued searching for an occult fracture in a pan scan.

JAMA. Published online 29 November 2016.


VISIBILITY
Peak of Inflated Expectations
Plateau of Productivity
Slope of Enlightenment
Trough of Disillusionment
Technology Trigger
TIME


2017
expectations
Connected Home
Deep Learning
Machine Learning
Virtual Assistants
IoT Platform
Autonomous Vehicles
Nanotube Electronics
Smart Robots
Edge Computing
Cognitive Computing
Augmented Data Discovery
Blockchain
Smart Workspace
Commercial UAVs (Drones)
Conversational User Interfaces
Cognitive Expert Advisors
Brain-Computer Interface
Volumetric Displays
Quantum Computing
Digital Twin
Serverless PaaS
5G
Human Augmentation
Enterprise Taxonomy and Ontology Management
Neuromorphic Hardware
Software-Defined Security
Deep Reinforcement Learning
Virtual Reality
Artificial General Intelligence
4D Printing
Augmented Reality
Smart Dust
As of July 2017
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Years to mainstream adoption:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau

Hype Cycle for Artificial Intelligence, 2021

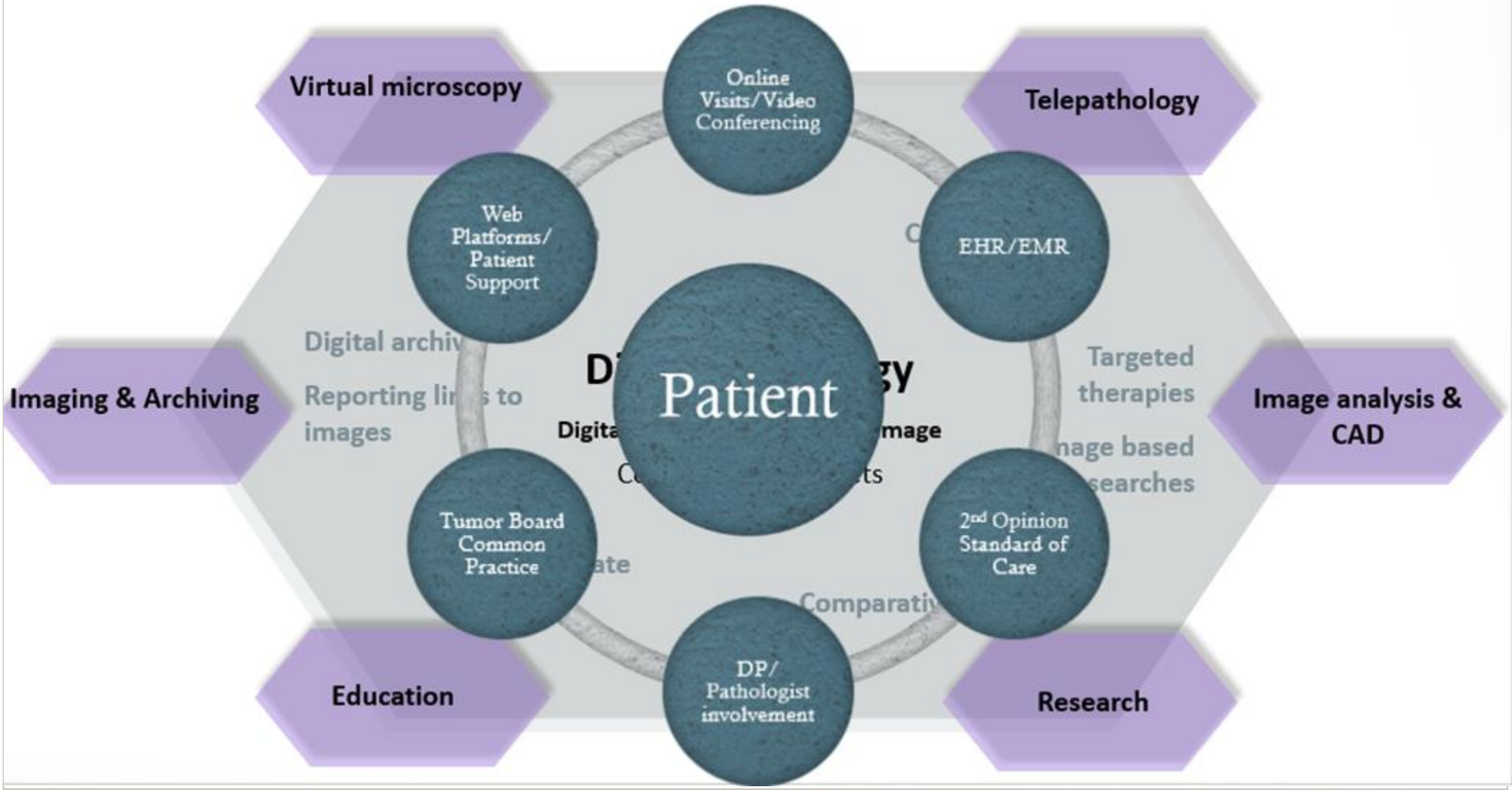
Plateau will be reached:

○ less than 2 years ● 2 to 5 years ● 5 to 10 years ▲ more than 10 years ⊗ obsolete before plateau

As of July 2021

gartner.com

Gartner


Virtual microscopy
Online Visits/Video Conferencing
Telepathology
Web Platforms/ Patient Support
EHR/EMR
Imaging & Archiving
Patient
Image analysis & CAD
Tumor Board Common Practice
2nd Opinion Standard of Care
Education
DP/ Pathologist involvement
Research

Thank You

Bene diagnoscitur, bene curatur.

"Something that is well diagnosed can be cured well."