## HEADLINER Revolutionizing surgery with surgical operating systems: The future of integrated healthcare



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13-14 September INTELLIGENT HEALTH 2023 Basel, Switzerland





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# Revolutionizing Surgery with Surgical Operating Systems

Intelligent Health Summit Basel, Switzerland – September 14, 2023

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Assistant Professor of Surgery - Harvard Medical School Massachusetts General Hospital









## Revolutionizing Healthcare: Introducing the Concept of a Surgical Operating System (**S**.OS)

A Blueprint for the Future of Medicine



## The Era of Technological Disruption



## ChatGPT

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## Innovation and Safety

"Technology is altering the landscape across various sectors. and the future is unfolding before our eyes."



## F1 Safety Evolution over the last 30 years and beyond





#### ◙ @\_projectf1 / ♥@\_projectf1

Gap to GAS

PROJECT F1





## Surgical Disruptions (in the last 200 years)

- General Anesthesia 1840s
- Antiseptic Surgery 1860s
- Endoscopic Procedures 1960s
- Cognitive Computing 2010s











## 20 years later .....







## What is happening in the Operating Room now ?







## **OR** Data Generation





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## Data sources and Analytics









### Video DATA

### More computing power





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More powerful/efficient techniques

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## Large amount of DATA



The average hospital produces roughly 50 petabytes of data every year. That's more than twice the amount of data housed in the Library of Congress, and it amounts to 137 terabytes per day.





terabytes of data during a win or lose a race.

#### **BACE TEAMS COMBINED TO GENERATE** 43 TERABYTES OF DATA FROM THEIR VEHICLES AT THE 2014 U.S. GRAND PRIX IN AUSTIN, TX

243 TERABYTES OF DATA COMPARED TO



EQUIPPED WITH HUNDREDS OF SENSORS, F1 CARS PROVIDE A STREAM OF DATA THAT'S ANALYZED THOUSANDS OF MILES AWAY IN NEAR REAL-TIME

.170 secs	.300 secs	.600 secs	1.923 secs
Round trip for race data	Round trip for race data	Difference between 1st	World record fastest
to transfer between UK	to transfer between UK	and 2nd place at 2014	F1 pitstop, set by Red
and U.S.	and Australia	Spanish Grand Prix	Bull in Austin 2013

RACE FANS GENERATED MORE THAN 2.3 TERABYTES OF AT&T MOBILE DATA DURING THE U.S. GRAND PRIX BY SHARING PHOTOS AND SENDING TWEETS, LESS THAN 1% COMPARED TO THE RACING TEAMS.







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# **The Healthcare**

Engl J Med. 2023;388(2):142-

153. 10.1056/NEJMsa2206117

#### SURGICAL SAFETY CHECKLIST (AUSTRALIA AND NEW ZEALAND)

Innovation dicho	rínnaesthesia ▶ ▶ ▶ ▶ ▶	Before skin incision <b>&gt; &gt; &gt;</b>		
minovation dichotomy		TIME OUT	SIGN OUT	
• Recent study reviewed 2,800+ i	npatient	CONFIRM ALL TEAM MEMBERS HAVE INTRODUCED THEMSELVES BY NAME AND ROLE     SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE VERBALLY CONFIRM     PATIENT     SITE	NURSE VERBALLY CONFIRMS WITH THE TEAM: THE NAME OF THE PROCEDURE RECORDED THAT INSTRUMENT, SPONGE, NEEDLE AND OTHER COUNTS ARE CORRECT	
records from 11 U.S. hospitals.	R ON PATIENT AND	PROCEDURE     ANTICIPATED CRITICAL EVENTS     SURGEON REVIEWS: WHAT ARE THE CRITICAL	HOW THE SPECIMEN IS LABELLED     (INCLUDING PATIENT NAME)     WHETHER THERE ARE ANY EQUIPMENT     PROBLEMS TO BE ADDRESSED	
<ul> <li>~25% of records had at least or event, preventable or not.</li> </ul>	AVE A : e adverse	OR UNEXPECTED STEPS, OPERATIVE DURATION, ANTICIPATED BLOOD LOSS?  ANAESTHESIA TEAM REVIEWS: ARE THERE ANY PATIENT-SPECIFIC CONCERNS?  NURSING TEAM REVIEWS: HAS STERILITY	SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE REVIEW THE KEY CONCERNS FOR RECOVERY AND MANAGEMENT OF THIS PATIENT	
<ul> <li>7% of all admissions had at lease preventable event.</li> </ul>	AENTASSISTANCE AVAILABLE Stoones DRENI? ATE INTRAVENOUS ACCESS INED	(INCLUDING INDICATOR RESULTS) BEEN CONFIRMED? ARE THERE EQUIPMENT ISSUES OR ANY CONCERNS? HAS ANTIBIOTIC PROPHYLAXIS BEEN GIVEN WITHIN THE LAST 60 MINUTES? YES NOT APPLICABLE		
• 1% had events of serious sever higher.	TY OF PMENT: DR SPECIAL EQUIPMENT) IS HEATRE, HAS IT BEEN ONFIRMED?	HAS THROMBOPROPHYLAXIS BEEN ORDERED? YES NOT REQUIRED IS ESSENTIAL IMAGING DISPLAYED?		
Bates DQ, Levine DM, Salmasian H, et al. The safety of inpatient health care. New		VES NOT APPLICABLE		



Healthcare, specially in surgery is a sector where technology's promise has not been fully realized.

"We have advanced machinery and data analytics, but the operating room still relies heavily on human judgment, sometimes leading to inefficiencies"

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**S.OS** is a conceptual framework that aims to seamlessly integrate surgical teams, operating rooms, patient data, and devices.

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### Standardization

Efficiency

Safety

#### Preparation, Creation, and Implementation

#### Foundational work

- Annotation 🖂
- Data Structure and Use 🖂
- Governance Policies, Regulations, and Oversight

#### Structural needs

- Video Data Acquisition Framework
- Creation of a Community 🖂
- Management through Data Lifecycle

#### Knowledge creation and dissemination

- Scientific Research 🖂
- Education 🖂
- Cultural Transformation



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## Surgical Operating System Framework

(10)

- Open Access Model to Promote Collaboration
- Standardization
  - Annotation
  - Data Structure
- Clear Policies and Regulations
- Transparency and Oversight
- Address Ownership Issues



## Surgical DATA

MGH 1811





## DATA Use and Structure

Objective: Establish a **framework for video data use in surgery** to improve collaboration and proposed methods to structure the use of surgical video for **clinical use**, **education**, **and research** applications.









## Annotation Framework Hierarchical Structure with Expandable Granularity



### **Temporal Events**

Phase (generic)

Step (procedure- specific)

Task (generic)

Action (generic)



### **Spatial Events**

Anatomic region

Specific anatomy

**General anatomy** 

**Tissue characteristics** 











## S. OS Features







**Technological** Integration



**User Interface** & Experience



Security & **Access Control** 



Communication & Collaboration



**Analytics &** Monitoring









## Process Management

- Orchestration Surgical Procedures
- SOS could manage the scheduling of surgical teams, rooms, and monitor surgery in real-time.



## **Resource Allocation**

- Maximizing Efficiency Allocation and Reallocation
- Staff
- Equipment
- Room



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for success across people, processes and technology



## **Device Management**



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## Data Management

### **Organizing Critical Information**

### Maintenance of structure data





## User Interface







## **Other Features**

#### I/O Operations

Networking

#### System Monitoring





#### ADVERSE EVENT RATE IS 66% HIGHER WHEN THE SURGEON IS UNDER STRESS



## Utilities and Apps

- Specialized software tools
- Pre-operative checklists
- Real-time patient vitals monitoring
- Intra-operative guidance
- Billing
- Documentation



## **Utilities and Apps**



TYPE OF FDA APPROVAL

510(K) PREMARKET NOTIFICATION

#### FDA APPROVALS FOR ARTIFICIAL INTELLIGENCE-BASED Devices in medicine

				DE NOVO PATHWAY
2016 11	Arterys Cardio DL		software analyzing cardiovascular images from MR	© PMA
2017.03.	EnsoSleep		diagnosis of sleep disorders	
2017.11.	Arterys Oncology DL		medical diagnostic application	
2018.01.	ldx	1	detection of diabetic retinopathy	
2018.02	ContaCT		stroke detection on CT	
	OsteoDetect		X-ray wrist fracture diagnosis	
2018.03	Guardian Connect System		predicting blood glucose changes	ENDOCRINOLOGY
2018.05	EchoMD (AEF Software)		echocardiogram analysis	
2018.06.	DreaMed		managing Type 1 diabetes.	
2018.07	BriefCase		triage and diagnosis of time sensitive patients	KADIOLOGI
	ProFound™ Al Software V2.1		breast density via mammogprahy	
2018.08.	Arterys MICA		liver and lung cancer diagnosis on CT and MRI	
2018.09.	SubtlePET		radiology image processing software	
	AI-ECG Platform		ECG analysis support	
2018.10	Accipiolx		acute intracranial hemorrhage triage algorithm	
	icobrain		MRI brain interpretation	
2018.11	FerriSmart Analysis System		measure liver iron concentration	
2019.03.	cmTriage		mammogram workflow	NEUROLOGY
2019.04	Deep Learning Image Reconstruction		CT image reconstruction	
2019.05	HealthPNX		chest X-Ray assessment pneumothorax	
2019.06	Advanced Intelligent Clear-IQ Engine		noise reduction algorithm	
2019.07	SubtleMR		radiology image processing software	OPHTHALMOLOGY
	Al-Rad Companion (Pulmonary)		CT image reconstruction - pulmonary	
2019.08	Critical Care Suite		chest X-Ray assessment pneumothorax	
2019.09	Al-Rad Companion (Cardiovascular)		CT image reconstruction - cardiovascular	
2019.11	EchoGo Core		quantification and reporting of results of cardiovascular function	ONCOLOGY
2019.12	TransparaTM		mammogram workflow	
2020.01 -	QuantX		radiological software for lesions suspicious for cancer	
	Eko Analysis Software		cardiac Monitor	

**Experimental** Phase

## Research : Intraoperative decision support

- Shrinking data for surgical training
- Technique that reduces video files to one-tenth their initial size enables speedy analysis of laparoscopic procedures.



SAIIL – MGH – MIT



## Computer Vision and Endoscopy

**Cadens - Imagia - Satis** © 2016 - all rights reserved



## a joint development from **Cadens, Imagia, Satis**



AI4GI Video and copy rights



## Real Time Phase Detection



Surgical Artificial Intelligence & Innovation Laboratory - Massachusetts General Hospital









#### **Experimental Phase**

## Artificial intelligence prediction of cholecystectomy operative course from automated identification of gallbladder inflammation







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Experimental Phase



## Surgical Fingerprint – POEM









## **Deviation Analysis and Detection**



















## Analysis of intraoperative video – Surgical Fingerprint

#### Experimental Phase

#### Case 1 – Uncomplicated Surgery

















## Surgical Fingerprint – Sleeve Gastrectomy







## Potential applications - **<u>S. OS Apps</u>**

- Attending notification system
  - Notify attendings if the trainees are nearing critical portions of the operation.

#### Peer Review

- Augmented Morbidity and Mortality meetings
- Board certification
- Hospital credentialing and recredentialing

#### Tele-mentoring

- Establish automated communication link to human mentor when error is predicted or identified.
- Battlefield and Rural Areas support, to medical staff who may not have the necessary specialty specific knowledge





## Knowledge Graph in Surgery

#### which can be used for

- Interactions of objects in surgery
  - Tool-action-tissue interactions.
- Relations of abstract concepts
  - Parkland scale and its components



Concept Graph Neural Networks for Surgical Video Understanding Y. Ban, J. Eckhoff, T. M. Ward, D. A. Hashimoto, O.R. Meireles, D. Rus, G. Rosman Under revision to IEEE Transactions on Medical Imaging 2022





## **Utilities and Apps**

# Automation







## Al and Mechanical Automation

#### Experimental Phase





Ken Goldberg Professor, Industrial Engineering and Operations Research William S. Floyd Jr. Distinguished Chair in Engineering, UC Berkeley





## **Error Handling and Recovery**





## Surgical Event Real Time Prediction



SUPR-GAN: SUrgical PRediction GAN for Event Anticipation in Laparoscopic and Robotic Surgery









### Analysis of intraoperative video with Decision Support.



## **5.** OS = Cognitive Augmentation

Information, Guidance, Safety, and Operational Efficiency





#### Moravec's Paradox

- *"Robots find the difficult things easy and the easy things difficult"*
- "Contrary to traditional assumptions, high-level <u>reasoning</u> requires relatively little computation power, whereas low-level <u>sensorimotor</u> skills require enormous computational resources"







## **Potential Failures**





#### **7 REVEALING WAYS AI FAIL**

## **IEEE Spectrum**



#### 2) Embedded Bias





https://spectrum.ieee.org/ai-failures

### Brittleness

- Embedded Bias
- Catastrophic Forgetting
- Explainability
- Quantifying Uncertainty
- Common Sense

• Math



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## **Real life examples of AI Failures**

HANDS ON THE WHEEL -

Another Tesla with Autopilot crashed into a stationary object—the driver is suing

Fail: Microsoft's AI Chatbot Corrupted by Twitter Trolls

Google Home outage hits users, '100 percent failure rate' reported

Apple's Face ID Defeated by a 3D Mask

IBM's Watson supercomputer recommended 'unsafe and incorrect' cancer treatments, internal documents show





## **Obstacles and Limitations in Surgical Al**

#### Data

- Limited access
- Limited annotation
- Regulation
- Systemic biases

#### Clinician

- Limited time
- Productivity pressure
- Culture

#### Researcher

- Limited exposure
- Innovation pressure



- Market pressure
- Culture

#### Patient

- Privacy
- Healthcare pressure
- Clinician relationship







## Surgical DATA Standards





## Surgical Al Governance Regulations, Policies and Oversight

#### Surgeons





2023/24











**Promote Diversity** 









## **Education and Training**





Medical School Curriculum



Publications









## **Professional Preparation**

#### Computer science

Ethics

Programing

Work force

Training

Credentialing

Simulations











## **Cultural Transformation**



#### SHARING DATA

#### SHARING KNOWLEDGE

#### CULTURAL DIFFERENCES







## Other Considerations

	Patient, Provider,
Who OWNS the data?	Hospital, Payor
Who gets the credit?	Who gets the <b>blame</b> ?

How do you explain Al-driven decisions to patients?

### Can you challenge the decision ?







## Surgical AI



## A few years from now .....







## At your local hospital.

## Initializing S.OS ...../

A Blueprint for the Future of Medicine







#### Faculty and Fellows



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Thomas Ward, MD Former Fellow







# Thank you!





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### GET INVOLVED









