AUTOMATED MEDICINE: THE FUTURE OF HEALTHCARE

It May Be Sooner Than You Think

Summer, 2019

This is the second in a quarterly series of white papers intended to stimulate discussion and strategy.

Abstract: As discussed in Issue 1 the future of medicine will be fundamentally reshaped by a fusion of three forces: Genetics, Artificial Intelligence, ("AI") and automation. The future of interventional and surgical capabilities has not been widely discussed. Demand for these services has risen dramatically in recent years and is forecast to increase significantly in the coming decades. As a result, demand is quickly overtaking supply in surgical and procedural services; however, current payment systems cannot support the labor intensive model. AI, advanced robotics, 5G Internet, 3D printing, miniaturization, and nano-technology will eventually fuse together to dramatically automate procedural and surgical services, alleviating the manpower shortage.

Issue 2: How 20% of non-emergent surgeries / procedures can be performed without physician (and little to no other medical professional) involvement by the year 2040.

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AI driven automation in medicine is advancing rapidly. To date, AI advances have largely been focused in the diagnostic area. Table 1 shows a recent list of the FDA approved AI applications.

Table 1: FDA Approved AI Applications

Company	FDA Approval	Indication
Apple	September 2018	Atrial fibrillation detection
Aidoc	August 2018	CT brain bleed diagnosis
iCAD	August 2018	Breast density via mammography
Zebra Medical	July 2018	Coronary calcium scoring
Bay Labs	June 2018	Echocardiogram EF determination
Neural Analytics	May 2018	Device for paramedic stroke diagnosis
IDx	April 2018	Diabetic retinopathy diagnosis
Icometrix	April 2018	MRI brain interpretation
Imagen	March 2018	X-ray wrist fracture diagnosis
Viz.ai	February 2018	CT stroke diagnosis
Arterys	February 2018	Liver and lung cancer (MRI, CT) diagnosis
MaxQ-AI	January 2018	CT brain bleed diagnosis
Alivecor	November 2017	Atrial fibrillation detection via Apple Watch
Arterys	January 2017	MRI heart interpretation

Source: Docwirenews.com; July 18,2019.

It is important to note that these applications currently supplement, but do not replace, physicians. It seems inevitable that this transition will ultimately occur; we believe the transition will be largely complete within 15 years. In the same Docwirenews.com article, Eric Topol notes that there were 14 FDA approved AI applications in January 2019; by April 2019 the number of FDA approved AI applications had increased to 26.

Many Internet connected remote monitoring devices have been approved for years. Common clinical conditions that use these technologies include Congestive Heart Failure (electronic scales) and diabetes (blood sugar monitoring). While not AI per se, they are an important part of the future automation of medicine.

Reimagining the Future of Surgery

Automating surgery and non-invasive interventions is exponentially more complicated than AI enabled diagnostic applications. Autonomous operating solutions ("AOS"), our term for future surgical automation, will *eventually* replace most non-emergent surgeon / physician performed procedures. However, this will likely take 30 + years due to:

- While much of the technology is developed / under development, important breakthroughs are still needed.
- Multiple technologies will need to be combined in an inter-related self-learning General Artificial Intelligence environment to achieve fully autonomous operations.
- Although AOS will need minimal labor, it will be capital intensive. This implies initial adoption will be limited to individual tasks and focused in densely populated areas.
- There are key barriers to AOS adoption (to be discussed in Issue 3).

The easiest way to illustrate AOS is with a hypothetical example.

Mary Smith: Hysterectomy patient - 2035

Mary is a 45 year old woman. She is somewhat overweight and has been experiencing vague aches and pain in her abdominal / groin area for the last two weeks, has difficulty eating and may have lost some weight. She conducts an on demand virtual visit with a primary care physician using her smart phone. Based on this visit Mary is referred to an OB Gyn physician. Mary selects 10 PM as the most convenient time for this follow up virtual visit, and consults with Dr. Cynthia Jones. Mary is unable to tell she is actually "talking" to an AI enabled computer. Dr. Jones askes Mary to connect to her home medical diagnosis unit ("HMDU"). The HMDU is voice activated and a holographic assistant helps her take and transmit her height, weight, pulse, blood pressure, respiratory rate and heart rhythm to Dr. Jones.

Based on this consultation Dr. Jones tells Mary that there is a 60% chance it is nothing serious – perhaps indigestion or a muscle strain. However, there is a 35% chance Mary has Uterine Fibroids and a 5% chance that there are cancerous lesions / tumors. Dr. Jones tells Mary the next step is blood work and an ultrasound which can be done via a mobile medical unit ("MMU") and asks what time would be most convenient for her. Mary is understandably upset, and Dr. Jones suggests a mild mixture to help Mary relax. Mary mentions she likes tea; 10 minutes later the drone drops off a 5 day supply of chamomile tea infused with a mild anti-anxiety medicine mixture. Mary relaxes and calls back to schedule the MMU for 6 PM Friday. Mary works and does not want to miss much time if it can be avoided.

The MMU detects traffic is heavier than normal, and phones Mary to confirm her arrival time. Mary indicates she will now be home at 6:45 PM. The self-driving MMU shows up at Mary's home at 6:40 PM. The self-driving

fully autonomous MMU performs a variety of tests; most results are immediately available. For Mary, the focus includes an ultrasound scan, basic blood work and urinalysis. The robotic assistant welcomes Mary into the MMU and completes the tests; Mary is back in her house by 7 PM. By 7:05 Mary is again speaking with Dr. Jones about the MMU results.

While not conclusive, Dr. Jones informs Mary that the diagnosis is now 75% Uterine Fibroids and 20% nothing serious and 5% cancer. When Mary asks about the cancer diagnosis, Dr. Jones shares that while it is possible, it is highly unlikely. Dr. Jones is confident in her diagnostic forecast as she has accessed and analyzed the information of over 1 million applicable patients in the last 5 minutes. Dr. Jones recommends a visit to the AOS center where the final diagnosis can be made, and if needed, all final testing and any necessary surgery will be performed in a single visit. Mary is interested but concerned because the nearest center is 45 miles away and she lives alone. Dr. Jones explains the process to Mary, and she is immediately relieved. Her appointment is booked for the following Saturday.

On Friday the drone delivers the HMDU again just as Mary arrives home from work. The virtual assistant helps Mary complete her pre-admission testing, counsels her on the necessary pre- surgery protocols and confirms the insurance preauthorization has been secured. All required patient “paperwork” is completed digitally and uploaded to the AOS center; her emergency contacts are notified and the AOS appointment is confirmed.

Saturday morning is rainy and cold. However, the self-driving car from the AOS center’s fleet arrives right on time. Mary likes cars that are easy to get into and out of, and she has reserved a SUV. Mary passes the time during the 1 hour drive reading a book and taking a quick nap. She arrives at the AOS center refreshed and relaxed. Seen from above, the AOS center can be intimidating; it is the size of 3 football fields. However, the welcoming centers are scaled just right; Mary selects the Asian themed entry as the music and décor help her relax. As she reclines in her chair, the welcome robotic assistant (her name is Alice) comes over and places an IV line; Alice never misses a vein. It is currently a saline drip; if needed, Alice will hang antibiotic and other medicines as needed.

Alice soon escorts Mary to the nearest AOS theater portal. Here Alice helps her change into a gown and assists her onto the specially designed operating table. The self-driving table takes Mary to the advanced imaging center where she will get her MRI (which provides the final pre-op diagnosis). Since the MRI is self-learning, it focuses just on the exact area of concern and the test takes 5 minutes to complete. The MRI results are immediately available; the news is good – the diagnosis is now 99% certain that Mary has benign Uterine Fibroids and the possibility of cancerous lesions has dropped to 1% chance. Mary has preapproved the surgery based on the reported results, and she is auto-transported to the sterilization chamber. Here she takes a shower with an advanced antiseptic agent. Her operating table has already been sanitized and the sterile sheets are put in place. The final pre-op tests do not detect any remaining contamination.

The Pre-Op robot, named Ann, starts a prophylactic antibiotic and hooks up a bag of IV fluid. Mary falls deeply asleep and she is administered supplemental oxygen. The pre-op portal is sealed and the door to the OR opens. Mary’s operating table advances into the operating theater and the team of surgical robots go to work.

The first robot, David, handles the anesthesiology; he has already perfectly calculated the appropriate medication and dosage. David also handles all the monitoring of vital signs and reports to the rest of the robotic team that all results are within normal range. Then the chief operating surgeon robot, Susan, starts into action. Using the prior imaging results, Susan has already calculated, down to 0.5 millimeter, the most effective surgical pathway and instrumentation. Susan decides to use a laser guided thermal scalpel. This instrument was recently identified through the global AOS AI network and the prototype was three D printed just 2 days ago. This is its maiden voyage and is predicted to be perfect for Mary’s anatomy and physiology.

Susan has never nicked an organ or a blood vessel. The new self-cauterizing scalpel works perfectly, and bleeding is practically non-detectable. The operation is over in 20 minutes. The uterus is visually examined using Susan's high definition cameras, and no abnormalities are detected. Tissue samples of the fibroids and some adhesions are taken; they are processed immediately by the pathology station located in the OR. Good news: all results come back negative and Mary does not have cancer.

It is time to close the small wound, decontaminate and exit. Cindy, the transport robot, carries Mary to the exit portal, where she undergoes a final antiseptic rinse. The surgical table disappears below the floor for decontamination and disposal services. The robots and the OR undergo a thorough decontamination process and are then checked for any residual germs / foreign bodies. None are found. From start to finish the entire process has taken 25 minutes, and the robots wait for their next patient. It takes 2 minutes for their next procedure to commence. The team is not concerned that they have another 40 procedures to complete in the next 24 hours.

Meanwhile, Mary is transported to a recovery area. Here she is weaned off her medications and her vital signs are monitored. The room and its robots are overseen remotely by a team of critical care physicians and nurses. Their help is rarely needed, and when it is, the robots can almost always deliver the necessary care. Mary's conditions are all normal; 15 minutes later she is on her way back to the welcoming center. Here she able to rest in either a recliner or a bed, whichever is most comfortable. Mary chooses the recliner. The recliner is fitted with a pillow specifically contoured for hysterectomy recovery; the pillow takes the pressure off the surgery area. The initial dose of her take home medications, mostly for pain, are administered.

Mary falls into a light sleep and wakes up 15 minutes feeling a bit hungry. She orders a meal (Asian of course) and takes another brief nap after eating. A few hours later she feels ready to leave. Kimberly, the discharge robot, orders her self-driving car. 1 hour later she arrives back at her house. Her personal assistant robot, Emma, is waiting for her and opens her door, escorts her to the sofa and asks what he can do to make her more comfortable. Mary says she is fine and just wants to watch a little TV. Emma places the perfectly contoured hysterectomy pillow and is there for the next 24 hours just in case something goes wrong. A few hours later Emma helps Mary to bed, where she has already placed another hysterectomy pillow. Mary awakens to the smell of eggs and toast; Emma has made the perfect breakfast. Mary leaves for work Monday morning feeling terrific.

From doorstep to doorstep the AOS experience took 8 hours. With 25 ORs, each AOS center performs 500 to 750 surgical procedures a day. There is a small team of surgeons and surgical nurses available in case a robot malfunctions, but it almost never happens. The AOS centers operate seven days a week, 365 days a year. The robotic team does not take vacations, lunches or coffee breaks; they are never tired do not care if they operate at 3:00 AM.

In **Issue 3** we discuss the benefits of AOS and the barriers to its adoption.