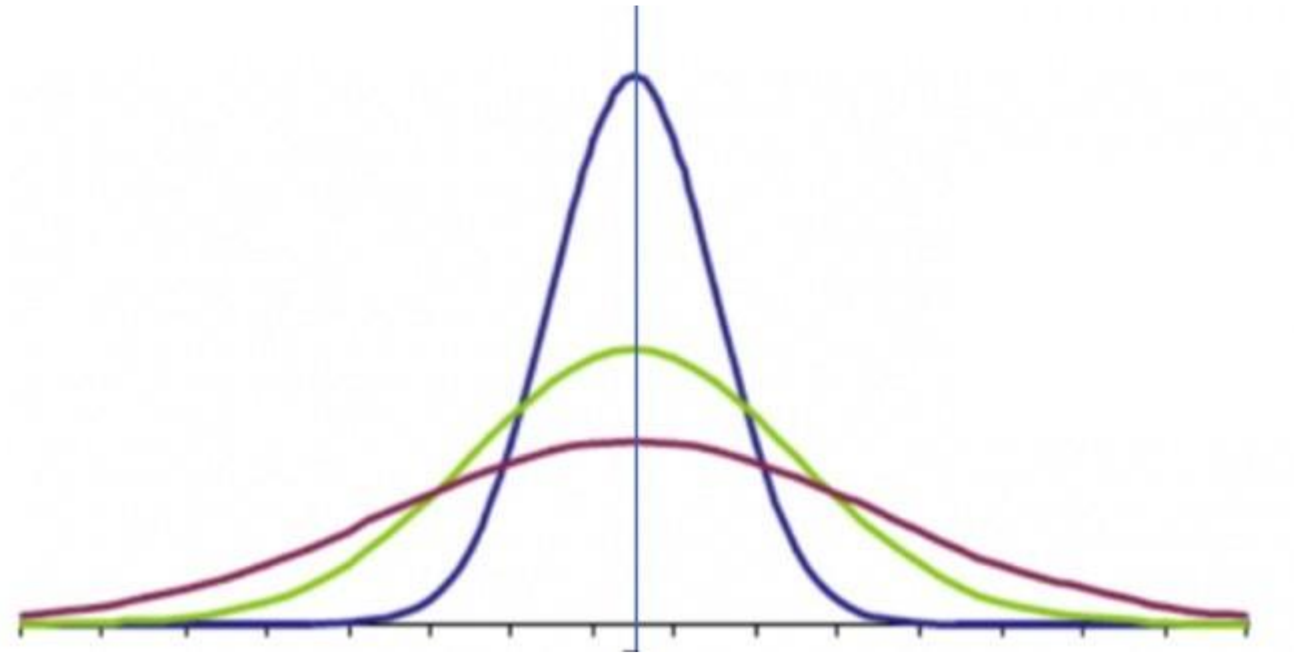

The (surgical) robots are coming! Run for the hills or for the robots?

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Stefano Bini

Founder/Chair Digital Orthopedics Conference (DOCSF) and Prof. Orthopedic Surgery UCSF

A look at the early data on the ROI and cost of implementing robotic surgery in Orthopaedics.

The costs of robotic surgery is not negligible. Most units cost approximately a million dollars and the net cost of a given procedure is increased by additional disposable single-use tools that can run $500.00-700.00 per case. Furthermore, software licensing agreements and maintenance contracts can add hundreds of thousands of dollars annually to the overall cost of robotic surgery. This seems an unnecessary increase in cost for a technology when, contextually, reimbursements for surgical procedures are already trending downward. Increasing costs is not high on anyone’s agenda.

The assumption that robots do not decrease the cost of care, however, needs to be challenged.

Robots are actuators attached to computers. An actuator is a device that acts on its environment. It could be a mechanical arm, a set of wheels, a soldering gun, or a laser; basically anything that can act on its environment. This actuator is controlled by a computer that tells it how to execute a command to act on said environment. The fundamental attributes of robots therefore, are very similar to the computers that control them: they are really good at doing repetitive tasks over and over with exacting accuracy. Autonomous robots go one step further and learn from their environment. But, in the end, they select an action from a number of perceived options and applied parameters. The computers that drive robots are programmed to achieve a pre-defined goal using their actuator (and the software is getting better daily). To some extent how good the robot is has a lot to do with how well suited the actuator is to the task it is assigned to do and how good the software is at manipulating that actuator. In other words

1. not all robots are created equal, and
2. they can only get better.

Robots can follow rules very accurately and repeat tasks *ad infinitum* much more consistently than humans can: they don’t get tired, lose interest, or vary from the plan. In so doing, robots execute the process outlined for them while minimizing variation and maximizing reliability compared to purely human processes.

The primary promise of robotics, therefore, is to decrease the variability in execution of an action, not to improve the expected outcome from a well-executed action.

In orthopaedic surgery, we are entering the era of robotic assisted procedures in which the robot is the copilot but the surgeon is still driving. Autonomous surgical robots are possible, but not yet in use. Assistive robotic technology enables surgeons to either do complex tasks in hard to reach places with ease (no need for wide exposure to introduce hands and instruments, no hand tremor, no slips) or do precision related tasks, like accurately cutting bones to match the shape of an implant. However, that does not mean they necessarily do it *better* than a human. If the goal is to screw two pieces of wood together, both a robot and a human can achieve the same exact result. The wood assembly will not differ so long as the assembly was executed well regardless of who, or what, performed the task. Thus when robots minimize variability they do not change the intended outcome: they minimize the standard deviation from that outcome.

The success of a robot should therefore be measured on that metric, variance from the mean, rather than whether it improves the mean itself.

This is illustrated in the diagram above where the mean at the center of all three curves has the same value but the standard deviation, a measure of how far from the mean the other values are, varies (2, 4, and 6). The broader red curve has a much larger variation whereas the narrower and taller blue curve clusters all the results very close to the intended target. The numerical value of the mean is the same for all three curves but if each represented a different surgeon, which would you chose? The value, or ROI, of a robot is therefore better measured by looking at just how narrow (how little variance from a target) it can deliver an outcome rather than comparing the mean value of the outcome achieved. This is important because in research we tend to measure the average (or the mean) and comparing those values between a robotically assisted procedure (the blue line) and one that is not assisted (the red line) may yield similar results on average even though one is far more likely to deliver that result.

That said, is there actual ROI (defined as an overall increased revenue or lower cost compared to the investment made into a robot) in minimizing variability without changing the mean? Absolutely. To everyone. *Predictability in healthcare carries a premium as it does in any other branch of the economy.* Patients want predictable results and payers will pay a premium for outcomes they can count on.

Generally speaking achieving a target is associated with a better outcome than not achieving the target. Better outcomes have, generally, lower costs. Therefore, since robots decrease outliers, and outliers frequently lead to increased expenses, robots should decrease costs. Stated differently, *average* overall costs of an individual procedure that uses robotic assisted surgery may increase, but the average overall costs for a set of robotic procedures should decrease compared to manual ones simply because there should be fewer outliers driving increased overall costs. And that is exactly what we are seeing in the early clinical results from robotic surgery.

What does the literature show? That robotic surgery, like in all other production lines in any industry, delivers.

A recent paper from NYU using the Medicare database analyzed costs from over 3000 total knee replacement patients of whom 519 had been treated with robotic assisted surgery (*Mont, Michael A., et al. "Health Care Utilization and Payer Cost Analysis of Robotic Arm Assisted Total Knee Arthroplasty at 30, 60, and 90 Days." The journal of knee surgery, 2019*). The authors calculated the total episode cost of care at 30, 60 and 90 days from surgery. In other words, they included the cost of the surgery itself and any billable event that occurred in the first three months thereafter. Overall, at 90 days the costs were lower by about 10% for the robotic knees due to fewer readmissions, emergency room visits and less need for post-operative care. In other words, by minimizing variability in surgical technique, there was an associated decrease in overall average cost of care in robotically assisted operations.

However, one could argue that the robotic patients were a special subset of patients pre-selected to do well. This argument is addressed in a paper from a different group looking only at Medicare bundle patients at a single hospital and treated under a single care pathway. This approach better avoids possible bias in the patient selection as all patients were treated the same. The results also showed lower 90 day costs in the robotic group (*Koenig, J. A., and C. Plaskos. "Ninety-Day Costs And Clinical Results Of Robotic-Assisted And Conventional Total Knee Arthroplasty." Orthopaedic Proceedings. Vol. 101. No. SUPP_5. The British Editorial Society of Bone & Joint Surgery, 2019*).

Detractors will point out that lowering the cost of care does not equate to improved clinical results. However, this too is not accurate. An example of the positive and measurable impact of robotics in on clinical results in orthopaedics is tied to the historical discrepancy previously reported for partial knee replacement surgery between high-volume surgeons showing great results, and national registries (which include results from all comers, even surgeons who do very few such operations) showing poor results. In this scenario, clinical results are defined as the need to re-operate on a patient because the prior surgery had failed for one reason or another. Several authors, including me, have previously documented how surgeon skill is closely tied to the success or failure of this particular procedure (*Bini, Stefano A., Guy Cafri, and Monti Khatod. "Midterm-adjusted survival comparing the best performing unicompartmental and total knee arthroplasties in a registry." The Journal of arthroplasty 32.11 (2017): 3352-3355*). Therefore, if robotics can take individual surgeon skill out of the equation, the results for robotic partial knee replacement surgery should be on par with those of the best manual surgeons even in national registries. And that is exactly what has happened: the failure rate of robotically assisted partial knee replacements in the Australian Joint Arthroplasty Register is on par with the rates published by high volume surgeons. This research shows how minimizing variability in the way surgical procedures are performed can lead to improved clinical results.

Several authors have looked at balancing the cost of a robot with the financial benefits of lower medical complications and have found a threshold effect where the increased cost is justified in centers performing higher volume surgery (*Moschetti, Wayne E., et al. "Can robot-assisted unicompartmental knee arthroplasty be cost-effective? A Markov decision analysis." The Journal of arthroplasty 31.4 (2016): 759-765. King, C., et al. "The effects of robot-assisted total knee arthroplasty on readmission and postoperative pain: are the added costs worth it?." Orthopaedic Proceedings. Vol. 101. No. Supp_5. The British Editorial Society of Bone & Joint Surgery, 2019.*). However, I have not seen a study that calculates ROI while taking into account the complex tax issues involved with depreciating capital assets and the impact on hospital cash flow of lower hospital length of stay and fewer readmissions. At some case volume, the increased capital and operational costs of purchasing and operating a robot will be negated by the lower overall cost of care.

When it comes to the payers, it is likely that insurers and self-insured organizations will come to see the use of robotics as lowering their overall risk and either offer a premium to surgeons for providing robotically assisted surgery or simply drive business to them.

Eventually, it is likely that patients will start to seek out robotically assisted surgeons as there is a social benefit that accrues the recipient from decreased surgical variability. In an upcoming post I will discuss robotics surgery and the results using PROMs (Patient Reported Outcome Scores) which are less clearly favorable (basically no change). In prepaid systems like Kaiser Permanente, integrated systems like the Cleveland Clinic, and any hospital participating in bundled care models (basically any system that is "at risk" and needs to pay for the consequences associated with excess variability), adopting robotic surgery should be a clear and obvious choice as, for now, it is one of the best example of where technology is delivering lower costs and higher quality.

So yes, the robots are coming, and for all the right reasons. You best run towards them.

(**Addendum**: *someone reading this text will raise the objection that from variation comes innovation and without innovation forward motion stops. They may therefore conclude that decreasing variability will kill innovation. They would be incorrect. Robotic surgery does not prevent anyone from changing the target for the robot, the goal they are asking it to deliver. From a scientific perspective, comparing two robotically performed procedures would allow for more accurate comparison of outcomes by decreasing the variability from that target outcome inherent in human driven surgery. Such comparative studies would be easier to perform and more accurate at discerning which procedure is better. I would argue that in fact, robotics may aid in driving and enabling surgical innovation, not hinder it*.)

Disclosure: As I am a strong believer in this technology and its potential to positively impact patients and the practice of medicine, I have a bias in favor of robotic surgery. As a closely linked result, I advise a company that manufactures and sells surgical robots.