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Are "Replicants" the Spine Surgeons of the Future?

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Many consider the 1982 movie *Blade Runner* by Ridley Scott (Warner Brothers) to be one of the more influential science fiction movies of all times. In its essence, a human police officer named Deckart played by Harrison Ford is assigned to hunt highly sophisticated robotic humanoids called "Recombinants," who have illegally infiltrated our planet earth and are threatening its human population courtesy of their superior skills. Since this movie was set to take place in Los Angeles in November 2019, this date provided a compelling occasion to compare the predictions cast 37 years ago in this movie with our present reality.[1] From our spine perspective, this movie and its vision of robotic humanoids being a threat to humankind due to their superior capabilities bears some relevance as we are on the threshold of introducing 2 major technical breakthroughs into our everyday spine practices:

- surgical robotic devices with navigation integrated to perform certain surgical tasks;
- application of artificial intelligence as a decision-making entity for spine care (for instance by deciding on surgical indications, techniques, and even selecting practitioners, hospitals, and nonoperative pathways).

More than being entertaining, a brief reflection on this movie and its accuracy of forecasts can show us how unpredictable forecasts can be (Table 1).

This comparison reminds us just how challenging it remains for us to render accurate predictions. As Table 1 shows, many forecasts in this movie were astonishingly behind actual realities, like smartphone technology, while others such as life-like robotic humanoids remain remote. In certain areas, technology breakthroughs happen in sudden and usually unpredictable surges, whereas in other areas physics, biology, or economic realities continue to pose seemingly insuperable obstacles. For us as humans, the introduction of certain technologies, for example cool smartphones and fully digitized images have been clear gamechangers (for the better???). Other technologies, like flying cars, may be in reach within a few years. Autonomous cars with integrated robotic and artificial intelligence (AI) capabilities are getting more commonplace by the month and may actually already statistically be safer than human drivers. The possibility of life-like autonomous robots that look and act like humans such as portrayed in form of the "Recombinants" still seems far-fetched. However, the more pressing immediate incarnation of "Recombinants" for us in medicine and spine surgery is the current introduction of AI and robotics in everyday medical practice. Both will create foundational changes to the practice of medicine in the not too distant future with far-reaching ramifications that we—based on the example of the *Blade Runner* analogy quoted above—probably are unable to accurately predict in our present day perspective.

The advent of robotics in surgery has been a bit of a mixed bag to date. For instance, over the last decade a robotically enhanced system specialized for prostatectomies has become a well-recognized option for prostatectomies due to its ability to visualize, manipulate and actually operate in a very tight space.[2] In endoscopy, for instance, "bots" seem to become a more realistic option for diagnosis and even intervention. In orthopedic surgery, however, the verdict remains unclear for total joint replacements about a decade after their introduction. More precise implant placement performed by robotic machinery appears to be offset by longer surgery times and higher rates of heterotopic ossification as well as possibly higher loosening rates.[3] Long-term outcomes and economics of robotic technology utilization remain unclear and leave current utilization more to patient/physician preferences—and marketing.

For spine surgery, the introduction of robotic technologies that integrate navigation and perform actual tasks like device implantation has become one of the most compelling business prospects for the medical device industry next to various biologics. Recently, the Food and Drug Administration cleared a first-of its-kind robotically guided needle biopsy and injection system for spine.[4] To date, the clinical application of spine surgery robotic devices are more feasibility projects rather than robust outcomes and comparison investigations. However, in the hands of early adopters and supported by industry, screw placement accuracy for open and minimally invasive procedures seems to be promising and may approximate human accuracy. In absence of clinical efficiency studies, the current obstacles to more common applications mainly arise out of the added high technology costs, with very limited cost-effectiveness data being available to date.[5-7] Apart from the clinical and economic feasibility, however, longer-term consequences—such as rendering tomorrow's surgeons incapable of placing screws with conventional analog techniques—are

Table 1. Comparison of Predictions Made in Original *Blade Runner* (Warner Brothers) Movie and Present Day Reality.

Forecast Reality Check 1982-2019	Our reality is on the spot or ahead	Our reality is behind, the movie is off
Video messaging	The 1982 movie actually underpredicted current smartphone-based communication tools like Facetime, etc	
Home technology	With voice-activated personal assistants and smart homes becoming the new norm for households the movie completely underpredicted	
Lie detectors		*Blade Runner* lie detectors were more comprehensive, but the general principles are still used
Weather		Los Angeles weather was famously rainy and foggy due to environmental changes. Sadly, overheating, droughts and forest fires have become the Los Angeles reality
Flying cars		They are way ahead in cool flying cars
Hairdryers		Ahead—it takes seconds, but they look quite similar
Photography	Our digital photography is way ahead of the analog prints used in the movie	
Robot sophistication		Their robots and underlying artificial intelligence are way ahead of reality
Medical care	Concierge care and remote vitals are a reality	

yet to be grasped. Already many fellowship applicants in North America have expressed their worries about *only* being trained with image guidance technology. Looking further ahead—will we still be looking for the most gifted surgeon to render care or rather a surgeon technologist who makes sure that a computer-assisted design is enacted?

The questions of the introduction of robotics into medicine and spine surgery, however, outrightly pale in comparison to the impact of AI in clinical medicine, which is taking place right now and which is clearly desired and actively supported by the marketplace and large-scale investors. Recently, large-scale data-sharing agreements being used by major health care systems like Mayo, Brigham and Women's, and Providence* with major tech companies like Amazon, Google, IBM, and Microsoft have been reported in the media.[8] The currently stated purposes are for purposes of creating more effective treatment algorithms for cancer, abstracting care notes into more systematic data collections that enable predictive modeling and cost-efficiency analyses. It is not far-fetched to foresee spine care algorithms being first suggested, then later proscribed, by AI-derived analytics. And it is not a far step beyond that to see the type of surgery, even the hospital and the specific surgeon would be selected by AI-derived means. These are not distant utopian nightmares but could become a practiced reality in the very near future. It is not at all clear how patients in various cultures around the world would accept such a premise if it were mandated rather than arose out of their free choice. And the role of the physician and surgeon in such an AI-driven health care decision model would likely be even more relegated to being a secondary mediator rather than serving their patients as an individual and (somewhat) independent practitioner.

As we are currently experiencing the introduction of robotics and AI in spine surgery, the dynamics of the marketplace and our various cultural and societal responses will ultimately decide their further acceptance and role in health care in general and our specialty specifically. Of course, it is incumbent on us to function as unbiased arbiters of strengths and weaknesses of the available iterations of these ever-evolving technologies. Perhaps more importantly, it would behoove us to become activists in exploring ethical and foundational effects of these technology applications in our field, lest we want to find ourselves on the defensive side in battle against the AI-empowered "Recombinant" spine surgeons of the future.

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Declaration of Conflicting Interests

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