The role of disruptive technologies and approaches in ERAS®: erupting change through disruptive means

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Disruptive technology. The term seems to provoke an unconscious sense of negativity and division because the word “disruptive” is often used to describe that which is unruly or troublesome. And yet, here we lay it together with technology, and create a phrase that in fact encapsulates and performs the opposite. While this term may seem infuriatingly familiar to those in business or finance, to the healthcare world, this term might be foreign or even unknown.

First defined in the mid 1990s by Clayton Christensen, a well-known business consultant, disruptive technology exploded and was quickly deemed one the most influential business ideas of the twenty-first century by the Economist [1]. This concept comprises technological innovation, of any and all types, with features or facets that disrupt the status quo: the established models, the conventional practices, the well-recognized and followed patterns. Yet these disruptions, while not always immediately welcomed, radically swept away the established to enact recognizably superior change. Top offenders found on the internet include artificial intelligence, high-speed travel, and robotics. The widespread arms of disruptive technology currently consume entities like e-commerce and ride-sharing while previously it elevated automobiles, electricity, and television. Clearly gaining weight and momentum in the business world, where does it stand within healthcare and surgery? It must hold a role and have laid a claim as it is a necessity for change, a necessity for accessibility, and a necessity for growth.

Almost simultaneously to when the term disruptive technology was coined, ERAS®, or enhanced recovery after surgery, took perioperative care by storm. Designed to improve quality of recovery and standardize care through multidisciplinary collaboration, ERAS® proved to have significant benefit across surgical specialties for both patients and healthcare systems. Its use quickly disrupted anecdotal practice or individualized treatment. However, similar to disruptive technologies, perhaps most akin to Sony’s early radios, ERAS® was initially used hesitantly and sparingly, only within the realm of colorectal surgery [2]. But as these principles showed considerable and clear benefit through compliance audits and big data sets (alas more disruptive technologies!), ERAS® extended beyond the initially described colorectal practices. Currently, there are over 30 published ERAS® guidelines, spanning 16 specialties including obstetrics and gynecology, cardiac surgery, and hepatobiliary. ERAS®, which we can consider a disruptive behavior that has evolved into a standard of care, has since spawned and/or spurred many disruptive technologies with its implementation. These have since led to significant breakthroughs and innovations in the following themes: (1) education; (2) prehabilitation and pre-operative care delivery; (3) intra- and post-operative care delivery; (4) patient experience; and (5) system’s building (Table 1). With many of these disruptive technologies spanning multiple of these themes, we will expand upon several to illustrate their impact and potential.

The first of these disruptive technologies discussed is the use of mobile applications for real-time collection of patient-reported outcomes, or PROs [16]. With compliance correlating to clinical outcomes within ERAS® pathways, assessing and tracking patient participation and experience can provide significant insight. Creation of a mobile application, accessible by any smartphone or tablet device, ensued and allowed patients enrolled in ERAS® pathways to offer feedback on perioperative care. Not only did this application also provide education and reminders for ERAS® pathway steps, but it surveyed patients for qualitative outcomes pre- and post-operatively. This disruptive technology creates a feasible avenue for real-time tracking and analysis with
Table 1 The disruptive technologies of ERAS®

| ERAS® disruptive technology                        | Benefit/disruption                                                                                                           | Pertinent references         |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| **A: Education**                                   | Video visits are non-inferior to in-person visits and offer convenience and accessibility                                    | Harkey et al. (2021) [3]     |
| 1. Virtual care                                    | Video visits are non-inferior to in-person visits and offer convenience and accessibility                                    | Harkey et al. (2021) [3]     |
| 2. Virtual reality                                 | HoloLens augmented reality aids visual learners through comprehensive practice and experience                               | Vavra et al. (2017) [4]      |
| 3. Infographics                                    | Infographics to improve patient and provider comprehension and recall of ERAS® pathway                                          | Hughes et al. (2020) [5]     |
| **B: Prehabilitation and pre-operative care delivery** | Ride-sharing to decrease patient transportation barriers and improve healthcare access                                      | Chaiyachati et al. (2018) [6]|
| 4. Ride-sharing                                    | Mail service prescription medication; pre- and post-operative treatment delivery (i.e., colon bundle, nutrition) to improve compliance and access | Schwab et al. (2019) [7]     |
| 5. Amazon Pharmacy                                 | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 6. Prescriptive analytics                          | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 7. Prehabilitation smart device sensors            | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| **C: Intra- and post-operative care delivery**     | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 8. Closed loop anesthesia                          | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 9. Automated continuous monitoring                 | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 10. HoloLens for pain control                      | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 11. Outcome situational awareness                  | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 12. Vertical compliance                            | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 13. Horizontal compliance                         | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| **D: Patient experience**                          | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 14. Patient-reported outcomes                      | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 15. Internet support groups                        | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 16. Voice assistants (i.e., Alexa)                 | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| **E: System’s building**                           | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 17. Team building simulation                       | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 18. Cumulative sum analytics                       | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 19. Lean principles                               | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
| 20. Time-driven activity-based costing (TDABC)     | Use of data mining, predictive modeling and machine learning to risk-stratify and improve patient care                      | Pickens et al. (2019) [8]    |
subsequent dynamic feedback for immediate improvements in perioperative care.

A similar offshoot followed PROs and was termed “vertical compliance” [14]. The ERAS® Interactive Audit System (EIAS) database maintains prospectively collected compliance data for patients in ERAS® centers across the world (hint—another use of disruptive technology). This data was utilized to create a model of tailored risk predictions based on individual ERAS® pathway adherence. This “vertical compliance” algorithm allows for real-time variable ranking through the electronic medical record such that pathway items can be categorized by effect on clinical outcomes. It further can identify and subsequently focus on patients who may be on paths to substandard outcomes.

With the arrival of 2020’s disruptive disaster, a disruptive technology that was just beginning to infiltrate surgical care was afforded rapid expansion and growth. Virtual care technology has been an exciting and evolving entity as it offers patients and providers significant convenience and accessibility. Prior to the COVID-19 pandemic, a randomized controlled trial demonstrated non-inferiority between virtual care video visits and in-person visits after simple laparoscopic acute care procedures [3]. With the arrival of COVID-19, society and the healthcare system have been dramatically altered, catalyzing swift acceptance and implementation of virtual care. Now virtual care visits are being utilized throughout all surgical disciplines, including pre-operative consultations and ERAS® education classes, daily hospital rounding visits, and post-operative assessments [23]. While this may have been rapidly implemented, it is sustainable, effective, eliminates social disparities, and is clearly here to stay.

Current systems make it not practical or even feasible for an individual surgeon to accurately track and monitor all of their own outcomes without significant support staff assistance. This need led to the development of “outcome situational awareness” (OSA) which is the examination and balance of the clinical and clerical responsibilities of a modern surgeon [13]. It is an interactive software platform that provides real-time individualized financial, patient-reported, and clinical outcomes for surgeons through automatic data population from medical records, administrative records, and interactive patient mobile applications to a centralized database. This platform allows for assessment and comparison of outcomes with peers and national standards. It additionally utilizes predictive analytics to alert to unexpected or negative trends before becoming clinically apparent and has been utilized for monitoring in real-time the benefits of ERAS® implementation.

If we can use technology to assess surgical outcomes, what about using it to analyze and predict disease-specific or treatment-specific patient outcomes? Deep learning through artificial intelligence can be “trained” to identify and/or predict disease or response to treatment that is more sensitive than the human eye. Demonstrated to be efficient in predicting pathologic tumor response to neoadjuvant chemotherapy in pancreatic adenocarcinoma and in identifying the malignant potential of pancreatic cystic neoplasms, it has also been used with ERAS® pathways to triage patient care and assess wounds for infection risk [24, 25]. One can bet this disruptive approach is only going to continue to infiltrate and expand across healthcare systems.

Other disruptive technologies encountered in conjunction with ERAS® include but are not limited to simulation for team building, cumulative sum analytics (CUSUM), and prescriptive analytics [8, 20, 26]. While each of these and the presented disruptive technologies begin through, yes, disruption, and perhaps, yes, significant frustration, each offers benefit and improvement if given the chance. We assessed Carolinas Medical Center of Atrium Health’s experience with disruptive technologies to establish an adoption benchmark. Their hepatobiliary surgical department follows ERAS® pathways for eleven procedures including open and robotic pancreaticoduodenectomy, open, robotic, and laparoscopic left pancreatectomy, and open, robotic, and laparoscopic major or minor hepatectomy. In order to identify the clinical penetrance of disruptive technology, we analyzed one of these procedures, robotic left pancreatectomy (RLP), assuming uniform permeation across all eleven hepatobiliary procedures as the same clinical team of nurses, providers, and educators exist throughout. After obtaining IRB approval, we identified 53 RLP patients between 2016 and 2020, and assessed adoption of 20 disruptive technologies (Fig. 1). While there was generalized improvement over time, in close examination of each technology, compliance adoption varies based on implementation requirements. Implementation can be either system-based, provider-based, or both provider- and patient-based (Fig. 2). Healthcare or hospital system–based technologies result in immediate implementation across all patients (Fig. 2A) whereas provider-based technologies are gradually adopted as an understanding needs to be established and then applied (Fig. 2B). Strategies that are both provider- and patient-based behave more erratically as compliance and adoption require patient dedication and investment outside of system and provider factors (Fig. 2C).

We know technology can be often daunting and sometimes overwhelming; however, it can drive growth and growth can drive improvement. So, while your armamentarium may hold the steps to a pancreaticoduodenectomy, allow it to also hold the steps for ERAS® implementation and its disruptive offspring (Table 1). We are in a new era where technology is limitless and if we embrace its extraordinary achievements, we can continue to improve for ourselves, for our patients, and for our healthcare systems.
Authors’ contribution Maria Baimas-George – concept, design of work, data acquisition and analysis, drafted manuscript, critical revision.
Nicolas Demartines – concept, design of work, critical revision.
Dionisios Vrochides – concept, design of work, data acquisition, critical revision.

Declarations

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Conflict of interest The authors declare no competing interests.

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