# Supplementary File 4

## Examples and arguments in publications related to disruptive technologies in health care

| **Reference** | **Disruptive Technology** | **Stakeholders** | **Areas of innovation** | **Promise** | **Challenges** | **Examples** |
| --- | --- | --- | --- | --- | --- | --- |
| Banda 2018 [UK] (17) | Regenerative medicine for intractable medical conditions | Patients/caregivers, insurers, hospitals, physicians, regulators | Devices (drugs) | Cure instead of treat; new forms of clinical delivery collaboration between therapy manufacturers and physicians |  | Discussion of six different business models as relevant for the UK |
| Chan 2006 [USA] (8) | Radiology: molecular imaging and computer assisted diagnosis | Patients/caregivers, Hospitals, physicians (radiologists and non-radiologists), manufacturers, insurers | Machine assistance; devices, provision of health care, setting, target market | Improved performance (speed) over existing approaches; downgrade skill mix (i.e. reduced need for radiologists), lower costs, might partly replace radiologists; reduce need for office visits and consultations with radiologists | require new skills and knowledge; competition from other specialists that aren’t radiologists, but who do imaging – e.g., cardiologists, orthopedic surgeons (reduce dependence on radiologists) | Portable ultrasound; computer-aided diagnosis, molecular imaging |
| Eltoum 2012 [USA] (18)  | Endoscopic ultrasound-guided fine needle aspiration (EUS FNA) in cytologic diagnosis in pancreatic pathology | Caregivers, hospitals, insurers, patients, physicians | Devices, provision of health care, setting, target market (unclear) | Improved accuracy of cytologic diagnosis, reduced number of indeterminate diagnoses, reduced need for tissue biopsyQuicker, less invasive, possibly by differently skilled providers, less costly |  | Might replace tissue biopsy in pancreatic pathology |
| Friedberg 2018 [USA] (27) | evidence-based mental health care for children and adolescents delivered via social media and utilisation of marketing science | Physicians, patients, caregivers, insurers | Provision of health care, devices, setting, target market shift | Better accessibility for rural and underserved populations, affordability, simplicity, scalability, sustainabilityImproved quality of services | Professional branding and marketing strategy replaces the business model for the sake of distribution and implementation of evidence-based mental health careTraining needs for therapistsTreatment outside of traditional structures | Cognitive-behavioural therapyState of Hawaii Child and Adolescent Mental Health Division programme “Help Your Keiki” [=child]Stepped care interventions, e.g. the UK Children and Young People’s Improving Access to Psychological Therapy Initiative (CYP IAPT), i.e. step-up care for non-responders who start with low-intensity care |
| Glabman 2009 [USA] (22) | Retail clinics – Telemedicine – Personalized Medicine/Genetic testing (pharmacogenomics)  | Hospitals, insurers, patients, regulators | Devices, machine assistance, mode of health care delivery, setting of health care | Retail clinics: operate outside of conventional physician officesTelemedicine: deliver care for patients more conveniently, often directly to their homes; expected savingsPharmacogenomics (personalised medicine): fewer blockbuster drugs, more indications, necessitates reshaping of business model for pharmaceuticals; development of diagnostic tests | Retail Clinics: The academies of pediatrics and family physicians argue that clinics disrupt continuity of care, have no uniform quality standard, and do not support the concept of a medical home because they fragment careTelemedicine: Some barriers to overcome are difficultly of use, litigation stemming from misuse, and lack of security in sending and receiving information Genetic testing: need to improve technologies – reliability and false positive/negative- fear of physicians over-ordering tests, and lack of evidence supporting safety and efficacy | Discussion of 5 potentially disruptive innovations (medical tourism and payment by smartphone not considered here) |
| Grady 2014 [USA] (9)  | Telehealth (remote monitoring, videoconferencing, m-health, patient-entered information, personal health record apps), Telehealth nurses | Hospitals, physicians, patients, insurers | Devices, mode of health care delivery, provision of health care, target market shift | Telehealth nurses may practice in community clinics, schools, prisons, or any setting in which on-site access to health-care providers is limited; they can also see more patientsBetter self-management by patients with chronic diseasesCost savings, save time on routine visits (e.g. prescription renewals)Reduction in visits to emergency rooms | Concerns about privacy/data security; current reimbursement policies too restrictivePatients may prefer face-to-face encounters | Potentially used in chronic illness and acute care End-stage renal failure Chronic heart disease ICU (use of robots)Mental health care with virtual collaborative care teams |
| Havighurst 2008 [USA] (25)  | Medical tourism and Health Savings Accounts, change in taxation of health insurance purchase | Patients, physicians, insurers, regulators | Health insurance | Better access to health care for uninsured or underinsured patients | Health insurance may lead to moral hazard regarding spending decisionsPhysicians benefit from existing financing mechanism (fee-for-service) and would oppose disruption | Managed carePrepaid group practice |
| Jönsson 2017 [EU] (15) | PCI | Physicians | payment mechanism | Partly replaces CABG, less invasive, transfer of power from surgeons to cardiologists | In the long term PCI and CABG are equally effective and cost differences disappear | PCI |
| Kaslow 2004 [USA] (10) | Vaccines based on plasmid DNA technology (gene-based) for infectious diseases, autoimmune disorders (self-antigen vaccines) and cancerProtein therapeutics for cancer, genetic disorders, protein replacement | Patients, physicians, public health (?) | Devices, drugs | Potentially requires fewer injections (multivalent vaccines)Replacement of traditional production and storage methods, more stable vaccines |  | Vaccination against HIV, malaria, TB |
| Kornowski 2017 [Israel] (19) | Transcatheter aortic valve replacement (TAVR) | Hospitals, regulators, patients, physicians, manufacturer | Devices, target market shift | Less invasive than surgery, faster recovery | Need to invest in operator trainingTAVR longevity and durability remains to be exploredHigh cost technology | A major deviation from the classic disruptive innovation theory occurred in the TAVR pricing strategy. This high-end entry might have been a reasonable strategy for the industry, but it created a significant economic barrier to adoption and/or prevented widespread utilization of TAVR devices globally. Anyway, it allows to make a profitable return from their investment at relatively early stages, without the need to undertake robust clinical testing. The goal was to capture as large segments as possible of the well-defined “high risk/no option” AS market, and then, to move into the lower-risk AS market. |
| Li 2012 [Australia] (20) | Information and Communication Technology (ICT) as a mechanism to support Nurse Practitioners (NPs) in Emergency Department | Caregivers, patients, hospitals, physicians, insurers | Mode of health-care delivery | Fast, efficient, quality care, continuity of careAlleviation of sub-acute workload and expediting the treatment of patients of lower acuityLower cost per patientShared responsibility between physicians and NPs | May require an expanded investment or rollout of ICTCould result in a change in responsibilities – i.e., shift from physicians to NPs | Use of Electronic Medical Records (EMR), electronic images through the PACS system, electronic medication module, ability to integrate decision support such as guidelines and alerts of drug reaction facilitated the advanced practice element of Nurse Practitioner’s role through contributing the timely and quality clinical decision making |
| McKinlay 2012 [USA] (23) | Retail clinics | Patients, hospitals, insurers, physicians, regulators | Mode of health-care delivery, provision of health care, setting, target market shift | Acute, chronic and preventive primary care for uninsured, underinsured people or those with high deductiblesLess costly (nurse practitioners and physician assistants instead of physicians)Convenience (reduced waiting time, better access, transparency about prices)Use of electronic health records | Physicians and professional associations oppose retail clinics, because they “*want to retain their licensed monopoly*”; continuity of care is interrupted | Vaccinations, physical exams, standardised treatment of limited list of conditions |
| Nam 2015 [USA] (11) | real time PCR for DNA amplifications, point-of-care diagnostic tests, POCT (with and without wearable devices)- genetic testing marketed to the public - mass spectrometry (MS) based automated microbial identification system, VITEK-MS, ; integration of gene sequencing and super computing; wearable devices | Hospitals, physicians, insurers, patients | Mode of health care delivery, devices, provision of health care, setting, target market shift | Organizational and clinical impact: MS-based method requires much smaller testing samples, and the testing can be performed much sooner, reducing the total time required to complete the processLower costs for point of care tests expectedImproved accessibility (POCT)Earlier diagnosis for patients with a range of acute and chronic health conditions. Moving diagnosis upstreamSelf-diagnosis by patient or differently skilled/experienced cliniciansWearable devices could push the frontier of point-of-care testingImplications in terms of model of care (decentralized) and a new role of hospitals | General hospital model still dominates in laboratory diagnostic. Need to change the model of care to address the needs of chronic patientsReduced reliance on specialized physicians and diagnostic consultations | mass spectrometry (MS) based automated microbial identification system, VITEK-MS |
| Niranjan 2012 [USA] (21) | Intracranial Radiosurgery (GammaKnife, CyberKnife) | Patients, physicians, hospitals, insurers, regulators, manufacturer | Devices; provision of health care, target market shift | a once inoperable tumor or malformation would be operable (new group of patients)Less invasive procedure, same-day discharge to homeReduced complicationsBetter cost-effectivenessProductive interaction between neurosurgery, radiation oncology and medical physics | Turf battles between proponents of competing technologies | About 50% of vestibular schwannomas and brain metastases as well as arterial malformations are treated with radiosurgery instead of microcsurgery |
| Paterick 2009 [USA] (24) | Retail clinics | Hospitals, physicians, insurers, patients, providers of retail clinics; professional associations of nurses and physician assistants | Mode of health care delivery, provision of health care, setting, target market shift | Standardized care for common medical problems and preventive services Improved access for patients especially when uninsured, underinsured or those with high deductibles in need for primary health care, chronic care, diagnostic tests and preventive servicesCost savings for insurersUse of electronic patient recordsAdditional entry point to hospitals via referrals, opportunity to expand the reach to patient | Hospitals and physicians might lose income depending on referral practices of retail clinics if different from physician referralMay impact patient-physician relationship and gatekeeping functionrange of standard to treat diseases and injuries, preventive services and chronic care measures remains limited |  |
| Pauly 2008 [USA] (26) | Health maintenance organizations (HMOs) in 1980s and early 1990s | Hospitals, physicians, insurers, patients | Setting, target market shift, payment mechanism | Limited spectrum of servicesLower cost | Legal barriers “*to offering anything but the (apparently) best medical quality*”,“*financing, organization, and regulation of most medical markets make change difficult*” | HMOs are a historical example of a disruptive technology |
| Rifai 2015 [USA] (12)  | Laboratory medicine: continuous flow analysis, dry reagents on dipsticks, pregnancy home testing, PCR, point-of-care testing, and use of MALDI-TOF mass spectrometry for pathogen identification | Hospitals/ patients/physicians/ regulators | A small, portable device designed to take a single drop of blood and give a readout for many different laboratory tests. | These advances enabled the introduction and performance of new tests on a large scale, some in a decentralized setting, in an accurate and a precise manner, thus leading to better diagnosis, more accurate prediction of disease prognosis, and improved patient management. | If the disruptive innovation is not considered an immediate challenge, it is less likely that it will make a difference. The risk is also acceptable, because if the disruptive innovation is poor or misguided, then it will fade away. | Smartphones as the hub of medicine including performing routine laboratory assays (with suitable hardware additions) in real-time for real-world biosensor data of most physiologic metrics. They can do a substantial part of the physical examination, and ultimately assemble a virtual medical assistant to process these multilayered medical data for each individual. rHEALTH; noninvasive prenatal testing (NIPT) |
| Rosenwasser 2017 [USA] (28) | Neuroendovascular surgery to treat ruptured cerebral aneurysms (coil embolization, flow-diverter, cerebral thrombectomy) | Patients, physicians, hospitals, insurers | Devices, mode of health care delivery, provision of health care, setting, target market shift | More therapeutic options, better outcomesbetter access to difficult to reach (anatomic) regionsreduced admissions, shorter lengths of stay, reduced management costsShift to more care being provided without need for an in-patient admission or shorter lengths of stay. More care provided in community settings | Neurosurgical training and expertise still requiredDifferent endovascular devices, minimally invasive, require different operation room equipment | Aneurysm treatment: transcranial approach replaced by endovascular approach)treatment of acute stroke: additional treatment option (endovascular devices for cerebral thrombectomy) provided by neurosurgeons within a regional hospital stroke referral network including telemedicine consultations |
| Saffitz 2012 [USA] (13)  | “*genomic pathology*”: Next Generation Sequencing (NGS)/whole-genome analysis | Caregivers/patients, physicians, hospitals, insurers | Machine assistance, devices, provision of health care, setting, target market shift | Faster, more accurate, more cost effective diagnosticspotentially significant increase in market as NGS becomes more cost effective and becoming more upstream i.e. facilitating earlier, more accurate and more cost effective diagnostic testing | Initially more expensive laboratory NGS platforms but these will, through time, significantly reduce costs for health system and users/patientsLikely reduction in type and volume of tests required. So likely to reduce number of skilled/qualified people requiredPotentially, move to diagnostic testing closer to user/patient and undertaken in differently equipped settings |  |
| Schulman 2009 [USA] (16) | Personalized medicine | Hospitals/ patients/physicians/ regulators | Diagnostic tests for personalized medicine | Personalized medicine offers the potential for revolutionary change in the practice of medicine. It also provides a unique window into the relationship between new medical technology, new business models for health care delivery, and the role of government in this unique marketplace.  | Currently, the regulatory pathway for development of diagnostic tests for personalized medicine applications is controversial and depends on whether the test or the information from the test kit is the product. | Diagnostic tests and digital photography |
| Schwamm 2018 [USA] (14) | Tenecteplase + discussion on the development of the stroke system of care (i.e. role of vascular neurologists in the care, selection of stroke centers, mobile stroke units) | Hospitals, patients, physicians, regulators | Mode of health care delivery, provision of health care, setting | Mobile stroke unit - Telestroke can replace the bedside neurologistQuicker access to effective reperfusions will lead to improved patient outcomes and decrease care burden and cost associate with stroke patients and need for ongoing subsequent treatment |  |  |
| Smith 2013 [USA] (7) | Multiple treatment in thoracic trauma, including: ultrasound for the diagnosis of cardiac tamponade; thoracoscopic techniques instead of thoracotomy; pulmonary tractotomy and stapled lung resection; endovascular repair of thoracic aortic injury; operative fixation of flail chest; and enhanced availability of extracorporeal lung support (ECMO) for severe respiratory failure | Hospitals, patients, physicians, regulators | Machine assistance, devices | Proved as effective interventions and some cases even faster (i.e. Pulmonary tractomy) – Indications in expansionUltrasound: Earlier diagnosis; better planned operative interventions. Thoracoscopy: quicker and improved hemostasis, patient diagnosis & management; reduced postoperative pain; shorter recovery period; return to pre injury level of activity; enhanced diagnostic and therapeutic utility. Pulmonary tractotomy: facilitates definitive control of bleeding; fast & efficient technique; obviate need for major pulmonary resections. Endovascular repair of thoracic aortic injury: lower mortality and morbidity rates. Fixation of rib fractures: reduction in chronic pain. Extracorporeal lung assist (ECMO): improved survival, miniaturization | Need to have high quality evidence (i.e. Lack of RCT for operative fixation of frail chest)Need to prove long term outcomes and consequencesNeed to define treatment algorithm – Availability of good quality evidenceHospitals need to have an updated and complete surgical armamentarium - Implications in terms of LOS |  |
| Sterling 2019 [USA] (29) | Virtual urgent care clinics as a patient-initiated consultation for urgent and chronic conditions available 24/7 | Physicians, insurers, health care organizations, telemedicine vendors | Mode of health care delivery, provision of health care, setting, target market shift | Convenience of on-demand service; improved access to health care, low prices, replacing house-calls | Availability of virtual platform technology and technical expertiseOrganization of the post-encounter process / definition of work-flow within the care continuity |  |