Opinion Paper

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Disruption vs. evolution in laboratory medicine. Current challenges and possible strategies, making laboratories and the laboratory specialist profession fit for the future

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Abstract: Since beginning of medical diagnostics, laboratory specialists have done an amazing job, continuously improving quality, spectrum and speed of laboratory tests, currently contributing to the majority of medical decision making. These improvements are mostly of an incremental evolutionary fashion, meaning improvements of current processes. Sometimes these evolutionary innovations are of a radical fashion, such as the invention of automated analyzers replacing manual testing or the implementation of mass spectrometry, leading to one big performance leap instead of several small ones. In few cases innovations may be of disruptive nature. In laboratory medicine this would be applicable to digitalization of medicine or the decoding of the human genetic material. Currently, laboratory medicine is again facing disruptive innovations or technologies, which need to be adapted to as soon as possible. One of the major disruptive technologies is the increasing availability and medical use of artificial intelligence. It is necessary to rethink the position of the laboratory specialist within healthcare settings and the added value he or she can provide to patient care. The future of the laboratory specialist profession is bright, as it the only medical profession comprising such vast experience in patient diagnostics. However, laboratory specialists need to develop strategies to provide this expertise, by adopting to the quickly evolving technologies and demands. This opinion paper summarizes some of the disruptive technologies as well as strategies to secure and/or improve the quality of diagnostic patient care and the laboratory specialist profession.

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Xerox, Kodak, Leica, Nokia, Nixdorf, Sears, BlackBerry, Blockbuster, MySpace, Toys R Us, Yahoo…. When you hear these names, one common denominator comes to mind. All of these companies were market leaders in their field at a given point in time and are now either minor players or have seized to exist, as they were unable to adapt to disruptive developments [1]. One of the main reasons for these companies failing was arrogance, in the belief that they could outlive the competitors by keeping on doing what they did, only better faster or cheaper. The laboratory medical profession might face a similar fate when it does not immediately adapt to disruptive technology, providing expertise and added value to patient care instead of sole numbers.

Laboratory specialists have done an amazing job over the past decades developing diagnostics from evaluating the color, odor, and taste of urine to today's highly automated, high-quality and speedy measurement of hundreds of different parameters from several different specimen. Today, laboratory medicine is an indispensable part of modern healthcare, contributing to the majority of medical decision-making. To be able to do so, laboratory specialists have focused mainly on the analytical part of the total testing processes. Currently, this analytical part is mostly maintained by laboratory technicians and service personnel from instrument manufacturers. Therefore, refocusing on the professions core competence, namely test selection and interpretation, is necessary to improve the diagnostic part of patient care in terms of quality, patient safety, efficiency and effectiveness. In addition, this strategy will prevent the laboratory specialist's profession from getting obsolete in the near future, ultimately reducing the quality of patient care.

Obviously, dealing with every patient sample/case individually, is unfeasible. Therefore, strategies must be defined and implemented to systematically provide added

value for patients. Hence, the aim of this article is to discuss four strategies that can contribute to this ambitious but urgently needed goal.

Rethinking the position of the laboratory specialist within the healthcare system

For decades, laboratory specialists have managed to incrementally improve laboratory diagnostics to the current high-end status. This has led to the belief among clinicians that it is laboratory specialists' purpose and assignment to provide only the results of the tests they ask for in the shortest amount of time, while maintaining a high quality. Hence, many laboratory specialists focus on the intra-laboratory processes, trying to improve these further. However, this strategy is very similar to that of the aforementioned companies.

When it comes to innovation, we can distinguish evolutionary from disruptive strategies. Trying to do current tasks better, faster or cheaper, either incrementally or radically, is supported by the implementation of evolutionary technology, meaning faster instruments, lower sample volume, new software for documentation and results transfer, et cetera. Disruption, on the other hand, is an event in which existing processes are being reviewed and a completely new strategy is being developed (lat. *disrumpere* = 'to break open') (Figure 1). Three of such disruptive strategies in laboratory medicine are discussed in this article.

Total quality management, process management, economic improvements, all are focusing on evolutionary innovation. Laboratory medicine specialists have perfected these tasks, making the laboratory by far the most organized and standardized entity within every healthcare system, adhering to SOPs, based on quality regulations [2, 3]. Compared to a school, the laboratory would be the pupil who is always perfectly prepared, never missing homework and getting only best grades; and what we are currently doing is like doing the bullies homework in fear of getting beaten up, namely waiting for clinicians to order the tests they believe to be appropriate and reporting back the results without asking questions. Surgeons do not let patients tell them how to perform an operation, nor do they wait patiently until patients have heard of some new surgical technique. They are experts in their field and know which treatment is best for the patient. So why do

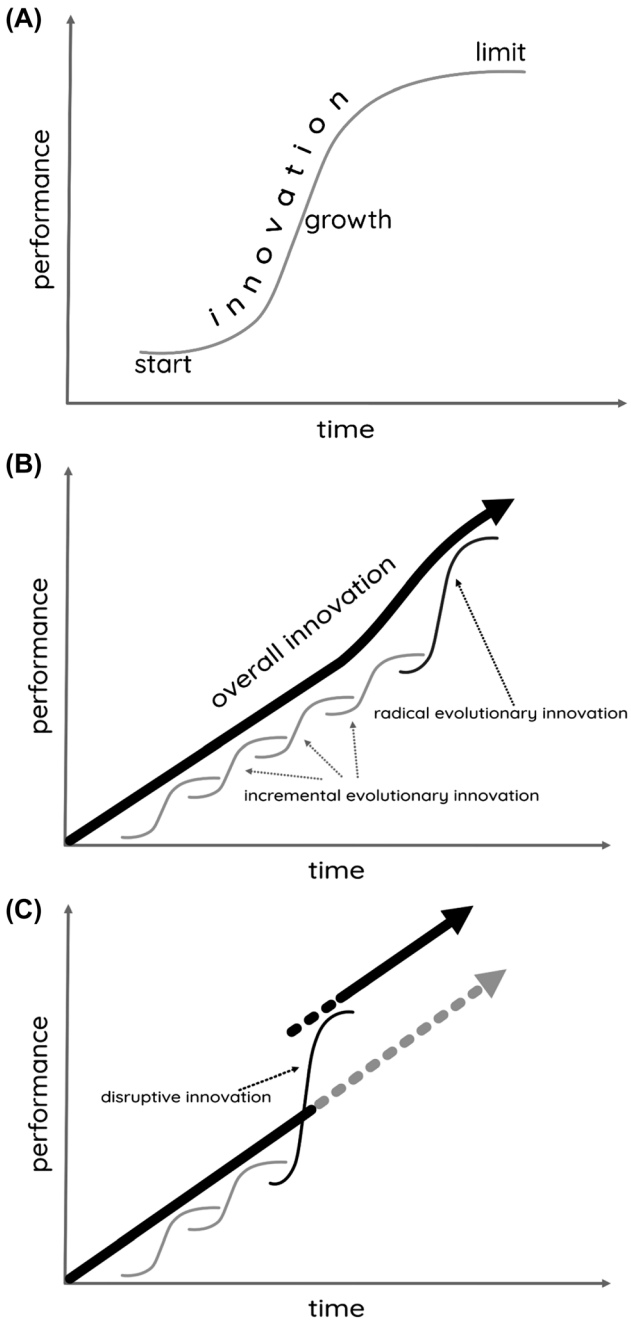

Figure 1: Evolutionary vs. disruptive innovation. (A) Innovations in general have a starting point which usually performs worse than the current standard. After some growth or expansion, the performance eventually exceeds and replaces current practices. (B) Usually such innovations occur incrementally (e.g. faster instruments, lower sample volumes, more accurate assays, et cetera). Sometimes such evolutionary innovations occur in a radical fashion (e.g. mass spectrometry, lab automation). (C) Disruptive innovation is marked by the fact of being completely new and different from the traditional procedures (e.g. molecular biology, artificial intelligence).

laboratory specialists leave test selection and interpretation to the surgeons and wait patiently when new parameters emerge until they have heard of it? A probable reason might be that many laboratory specialists see the clinicians as the prime beneficiary of the laboratories output. However, this is like companies regarding their retailers/distributors as customers, not the person buying their product. The actual prime beneficiary of the laboratory data is the patient and similar to the above-mentioned situation, laboratory specialists, as experts in their field, know best which tests are appropriate to diagnose the patient. Therefore, laboratory specialists have to start participating in patient care by providing their expert opinion and judgment in collaboration with clinicians.

A recent survey of the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) Working Group on Preanalytical Phase (WG-PRE) showed that the majority of clinicians would very much welcome assistance from laboratory specialists in test selection and interpretation and would appreciate the laboratory altering their initial order, if it benefits the patient [4].

In laboratory medicine, technology has come to a point where it is not improvable by much anymore in terms of speed, reliability, or quality. But that is not necessary. Applying a hedonistic approach/regression, demands for speed, quality, expertise, or cost seem quite heterogeneous, depending on the individual setting (Table 1). The current laboratory performance absolutely suffices most clinical situations, it often even over-performs. It is common knowledge that the parts taking up the most time in the total testing process is sample transport and centrifugation, while the 5-min analytical phase is negligible in most cases. In the strive for faster turnaround times, it therefore seems strange that the majority of the laboratory profession focuses on improving the latter phase, instead of focusing on transport, centrifugation or reporting. The pre-analytical processes could easily be reduced by implementing instruments that analyze whole blood instead of plasma and being operated decentralized. Apart from higher costs and increased administrative necessities, another possible reason for not implementing such point-of-care testing (POCT) instruments might be that the laboratory profession faces the fear of this strategy cannibalizing its own profession. A mistake many large companies have made and subsequently fell into oblivion. POCT is not a threat, it is a chance, and it is to the benefit of the patient. Laboratory professionals are or should oversee any laboratory diagnostics performed in the individual healthcare setting, regardless of their location. Only then, high-quality analytics with low error rates is guaranteed [5].

The same is true for other emerging technologies such as artificial intelligence or demand management strategies. Although living in a system which reimburses sickness rather than health, strategies need to be implemented aiding in providing a more personalized and selected approach, even if this means lower reimbursement than the commonly used "*shotgun-diagnostics*" (widespread selection of laboratory tests, regardless of the patient's individual symptoms and not necessarily contributing to patient care) [6].

Laboratory specialists should refocus and develop strategies to best serve the patient, disregarding the wishes of clinicians. Ideally, this "disruption" will be made in collaboration with clinicians, but when facing resistance it must undoubtedly be the laboratory specialist who is in charge of selecting the right test at the right time for the right patient [7].

Laboratory demand management strategies and laboratory diagnostic algorithms

Leaving test selection and interpretation to clinicians has led to a severe over-(ordering tests not needed for patient

Table 1: Hedonistic evaluation of demand.

		Importance of			
		Quality	Speed	Cost	Expertise[a]
Hospital	In-patient ward	■	■	■	■
	Out-patient ward	■	■	■	■
	ED	■	■	■	■
	ICU	■	■	■	■
Private practice		■	■	■	■

[a]Aid in test selection and interpretation. The quantifications are purely subjective. The Table should only demonstrate the heterogeneity in demands, depending on the setting.

care) and underuse (not ordering tests needed for patient care) as well as incorrect interpretation of laboratory tests. Reported numbers reach from 20 to 70% of orders being deemed overused and 40–45% being underused [6, 8–11]. The correctness of test interpretation is partly depending on the physician's clinical experience, but numbers of incorrect interpretations are far too high [12–14]. This circumstance may not only lead to a substantial economic impact, but more importantly, may jeopardize patient safety due to unnecessary follow-up diagnostics and therapy or missed/delayed diagnosis. The latter is a major contributor to the overall number of medical errors, the third leading cause of death in the US, as found by Makary et al. [15].

There are several ways of overcoming this issue, all of which subsumed under the term *laboratory demand management* [16, 17]. Such strategies include automated or individual educational interventions, gate keeping strategies, such as re-testing intervals, harmonization of test panels/request form design and review of offered tests.

Several studies have proven these strategies to be effective in overcoming the excessive and inappropriate use of laboratory tests [18–26]. Several initiatives around the world have been developed, providing freely available and evidence-based recommendations on appropriate laboratory tests use [27–33].

All mentioned strategies can address the overuse of laboratory resources. However, underuse, which can affect patient safety may be even more severely than overuse, can only be addressed by implementing so-called *laboratory diagnostic algorithms*. These algorithms consist of subsequent 'if > then' sequences (Figure 2). As mandatory prerequisites, these algorithms must be based on current evidence, developed in collaboration with clinicians and updated regularly. Benefits and limitations of this strategy is discussed elsewhere [34]. However, when considering to implement such algorithms, it has to be acknowledged that, according to the Medical Devices Regulation, the *In-Vitro* Diagnostics Regulation and the part 11 of Title 21 of the Code of Federal 20 Regulations (21 CFR/Part 11), laboratory software, performing actions different from storage, archiving, communication or simple search, have to be secure, backward traceable and validated, if they influence patient diagnosis or treatment, with some differences between Europe and the US [35–38]. This includes software triggering demand management strategies or artificial intelligence systems, discussed in the next section.

Nevertheless, as the next logical step, implementation of IT systems aiding laboratory specialists in test interpretation or selection will be necessary.

The use of artificial intelligence in the laboratory

As mentioned, the laboratory incrementally produces more and more data. However, following the premise "more is not always better", these masses of data may contribute to information overload and subsequently reduce the medical outcome and quality of patient care rather than improve it [39, 40]. As human cognition is unable to grasp the information concealed in this vast amount of digital data, IT systems aiding in revealing the hidden knowledge need to be employed.

Such systems, crawling through tons of data, flagged or unflagged, mimicking the human brain, by trying to make sense thereof, are called artificial intelligence (AI) systems, models or algorithms. The assessment of the information masses from multiple electronic sources, aiming to reveal otherwise unrecognized patterns, is called "big data" [41] (Figure 3). Despite the premise of standardized data structures, currently data formatting standards are mostly being neglected [42]. In a recent survey among laboratory stakeholders, legal requirements, high investment costs, lack of proven clinical benefits, number of decision makers, and privacy concerns were identified as the main barriers, preventing laboratories from adopting AI-based processes [43].

In the same survey, 15.6% of participants stated that AI is currently used in their organizations while 66.4% felt they might use it in the future. Indeed, an increasing number of medical AI models are being registered at and approved by the Federal drug and food administration (FDA), however, only a minor part thereof has been registered in laboratory diagnostics to date, most of which in diabetes diagnostics [38, 44]. The reason might be found in the fact that other diagnostic disciplines rely more on image recognition, a task which does not necessarily have to take other patient information into account and is therefore more easily being performed by machine learning algorithms, compared to laboratory result interpretation. However, the number of articles related to artificial intelligence studies, based on laboratory medicine data, has been exponentially increasing over the past few years [45]. This leads many experts to believe that AI will disrupt laboratory diagnostics in the near future [46, 47].

In the above-mentioned survey, most participants had an unsure attitude on what they would need to adopt AI in the diagnostics space [43]. Eighteen percent of respondents were unsure about AI use or stated never to use it in their organizations. This behavior might be based on the fear of replacement by technology, similarly to the

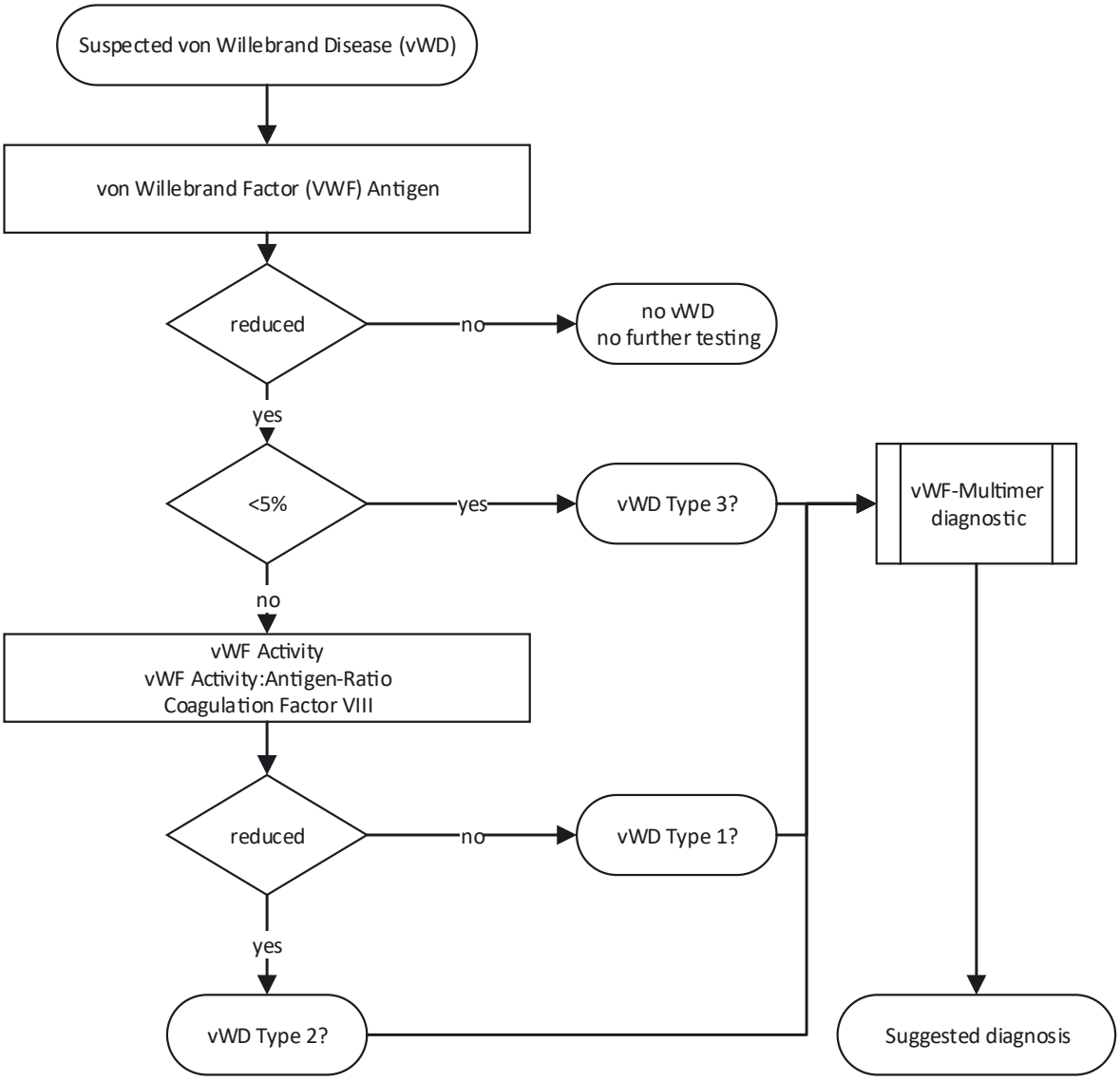

Figure 2: Example of a laboratory diagnostic algorithm. This algorithm is only meant for the purpose of demonstrating the principle of diagnostic algorithms and does not claim to be complete and/or accurate.

above-mentioned fear of cannibalization of the laboratory profession by the implementation of POCT diagnostic. However, this fear is at least partly unsubstantiated. Critical thinking, intuition and creative problem solving are particular human virtues, impossible to be performed by algorithms, which are capable of handling only situations which they have been trained for. Several studies have shown that according to the *Gestalt* principle, the combination of human and artificial intelligence has a better outcome than the sum of its parts [48–51]. Even Gary Kasparov, former world chess champion, famously beaten by *Deep Blue*, one of the first publicly noticed AI systems, expresses his concerns on rejecting the opportunity of harnessing the benefits of this new technology [52]. AI systems could aid laboratory professionals by identifying new diagnostic patterns (e.g. detecting COVID using routine laboratory tests) or critical patient results, calculating more appropriate reference intervals for the local population, verifying test results, avoiding preanalytical errors, surveilling quality management, suggesting result interpretations and much more [53–59].

In conclusion, AI is not a technology that will replace laboratory medicine professionals, but rather improve their value, by providing the opportunity to focus on more medical tasks and individual patient care, thereby integrating the profession in healthcare settings as an indispensable part thereof.

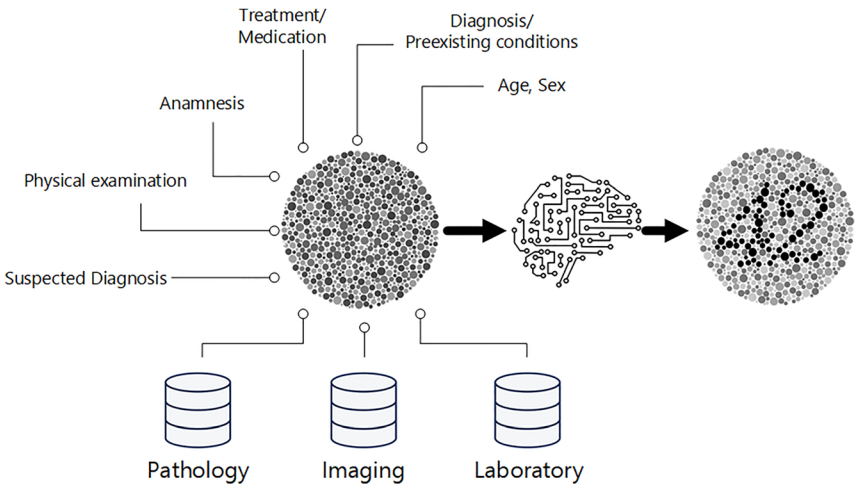

Figure 3: Big data and AI.

Integrated diagnostics in healthcare

This fourth strategy is possibly the most important one. Healthcare processes have traditionally been organized or evolved around medical disciplines rather than the patient. Every discipline is usually located in its own facilities, handling its own budget and resources, being led by a medical specialist in this field and focusing primarily on the own medical discipline. In case other disciplines are needed in order to diagnose or treat the patient, either the patient must be sent to the appropriate facility, sometimes far apart and difficult to find, or a consultant physician from that department has to come and examine the patient. This system intrinsically comprises the primary objective of benefiting the department rather than the patient.

The same is true for diagnostic departments, such as radiology, pathology, nuclear medicine and laboratory medicine. These disciplines are mostly not interconnected, making interdisciplinary diagnostic pathways near to impossible. It is again up to the treating clinician to review all diagnostic reports within the electronic healthcare record (EHR) system and formulate a synoptic conclusion.

This so-called vertical or silo system is inefficient on many levels. Resources, such as staff, instruments, equipment, etc. must be provided in duplicate with partly overlapping responsibility and/or usage. Poor communication among departments and lacking interdisciplinary efforts may subsequently lead to overuse of diagnostic resources and, most importantly, unnecessary delay in the patient's diagnostic and treatment process.

In order to categorize strategies to improve these structures and habits, Gabutti et al. describe three main pillars of change [60]. They named these the *progressive patient care model*, the *patient-centered approach*, and the *lean approach*. All of which follow the idea of transforming healthcare settings into non-wasteful, sleek and patient-centered processes. The progressive patient care model can be thought of as an "organizational container", pooling patients and organizing patient-flows around the acuteness of patients' conditions and not around the specialty they are concerned with. The patient-centered approach represents a set of pathways to "fill" these containers, while the lean approach should be conceived as the "kit of technical tools" necessary to do so effectively.

Applied to medical diagnostic specialties, the progressive patient care model would be a collaborative diagnostic center, that contained all the diagnostic disciplines. The patient centered approach would be the possibility for clinicians to order evidence-based diagnostic pathways for the individual patient, without having to indicate exactly which diagnostic tests or imaging procedure has to be performed. Assuming that laboratory testing contributes to the majority of diagnostic prognostic or therapeutic decisions, a combination with imaging diagnostic would most probably cover 90–95% of all such decisions, especially in the most frequent and burdensome diseases, such as cardiovascular disease or cancer [61]. Additionally, discussions about who gets to analyze what (e.g. liquid biopsy) would be obsolete.

The lean approach, would be a data warehouse, containing all the patients' medical information, ideally including AI models, providing suggestions for diagnostic procedures or interpretation of results. Lean healthcare, as a spinoff of lean management, developed by Toyota in the 1960s, has emerged since the early 2000's [62]. This principle aims is to avoid useless tasks, processes or activities, which do not improve or contribute to patient care, thereby improving the quality of patient care and patient safety,

eliminating delays and reducing the length of stay [63]. Lean healthcare imitates the value stream principle of the manufacturing industry, with the "value" defined as anything that improves patient care and experience, and the "value stream" being the journey of the patient through the healthcare environment [63]. According to the seven types of "waste" or "muda" from the lean principle the current way of patient care would be graded as highly inefficient: Waste of processing (identification and correction of faulty processes), waste of time (waiting for patient's, results, staff, et cetera), waste of movement (unnecessarily moving the patient), waste in transportation (transportation of resources, materials and staff), waste of making defective products (duplication of information, lack of value for the patient), waste of inventory (excessive inventory), and waste of overproduction (overuse of resources such as diagnostic testing) [64].

We have become so blind to these flaws in daily patient care that the sense of urgency for change, the initial and most important step in change management, according to the *Kotter 8-step process for leading change*, is rather low [65].

Generating an integrated diagnostic center would help reduce several of the above-mentioned waste types. Resources and data could be shared, duplication of information and overuse could be avoided, sample transportation among diagnostic facilities could be reduced to a minimum, et cetera.

In this context, responsibilities among individuals and professions in healthcare must also be reassigned. Rather than being strictly focused on specific medical disciplines, multidisciplinary roles, covering functional units may be needed. Educational curricula would need to be adapted accordingly.

Of the three latter strategies, discussed in this article, only artificial intelligence could be regarded as disruptive technology, whereas demand management and integrative diagnostics would be defined as radical evolutionary innovation, leaving aside the fact that it should not have to be discussed in 2022 if or how to implement these strategies, as they should have been part of the core task of the laboratory specialist profession from the beginning on.

The main preconditions and simultaneously the biggest obstacles in the way of implementing either of the last three strategies are the hospital management and the IT department. Like the initially mentioned companies, hospital management will focus primarily on short-term expenses and on the "profitable market", rather than invest in disruptive innovation and technology, which almost always is more costly in the beginning compared to incremental evolutionary technology. The IT department, at least those of public hospitals, is often understaffed, underpaid and overworked. Therefore, implementation of disruptive technology, such as demand management algorithms, AI models or software for collaboration and integrated diagnostics is mostly far out of scope.

Nevertheless, laboratory specialists need to rethink the way they are providing their expertise to patient care. In a *Manifesto for the future of laboratory medicine professionals*, Lippi and Plebani recently referred to current practices of laboratories in medical reporting as "tossing laboratory results over the fence" [66]. Instead, laboratory specialists should use their expertise to convert results into clinical information and provide diagnostic stewardship. Every laboratory specialist, who has been asked by clinicians what his/her job/task/purpose is within the laboratory or at the hospital – and I believe there are some – should take this question seriously and try to answer it for the local setting. If clinicians are not aware of what the laboratory specialists' purpose is within the local setting, something needs to change.

In contrast to the initially mentioned companies, medical laboratories mostly have the benefit of little to no competition. However, as the current COVID pandemic shows, this could change quickly as other non-laboratory stakeholders may enter the market as soon as it becomes profitable. In some countries the Exodus of hospital laboratories into private hands, primarily focusing on profits, has already begun or is even well advanced. The need for a change is obvious and I hope that this article has illustrated the current situation and helps in creating the necessary sense of urgency.

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