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THE FUTURE OF MEDICAL LABORATORIES AND CLINICAL DIAGNOSIS OF DISEASES

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Abstract

Background: Laboratory tests are actually requested for a) predicting susceptibility to diseases, b) preventing diseases by identifying risk factors, c) diagnosing many pathological conditions, often at an early stage, d) prognosticating, e) monitoring disease progression, and f) personalising treatments to achieve the best possible outcomes.

Methodology: New technologies are increasingly being used in clinical laboratories, such as amplification and sequencing of universal gene targets, Detecting the Virus Antigen and Circulating cell-free DNA (cfDNA) that has been detected in cancer, autoimmune diseases, infectious diseases, stroke, sepsis, trauma, and pregnancy.

Results: In routine clinical practice, there are several parameters that must be considered as a reliable biomarker, such as high sensitivity, specificity, and positive predictive value (PPV) that, increasing the likelihood of making the best decisions for the individual's optimum care.

Conclusions: Clinical laboratories are not only testing services, but also knowledge services that make use of all available communication channels; they provide more than just assay results; they also provide knowledge and education.

Keywords: medical laboratories and clinical diagnosis, future of medical laboratories, diagnosis of diseases with medical laboratories diagnosis.

1. Introduction

Laboratory medicine is becoming increasingly important in modern healthcare systems, as in vitro diagnostic tests are now used at nearly every stage of managed care. Laboratory tests are actually

requested for a) predicting susceptibility to diseases, b) preventing diseases by identifying risk factors, c) diagnosing many pathological conditions, often at an early stage, d) prognosticating, e) monitoring disease progression, and f) personalising treatments to achieve the best possible outcomes [1].

In recent decades, technical and organisational advancements in laboratory testing have progressed in tandem with improved knowledge of the pathophysiology of human diseases and changes in healthcare delivery, thereby supporting a paradigm shift from diagnosing and monitoring advanced diseases to an equally widespread predictive and preventative approach [2]. Most organ diseases (for example, liver, kidney, and thyroid pathologies) can only be detected with the help of laboratory tests. Many of these conditions are asymptomatic in the early stages and thus unlikely to be clinically detected. Early detection of asymptomatic diseases should lead to better disease management and less erosion of public and private (i.e., out-of-pocket expenditure) economic healthcare resources. Some laboratory biomarkers (e.g., cardiac troponins, glycated haemoglobin, anti-transglutaminase antibodies) were developed and introduced into clinical practice specifically for this purpose. Most infectious diseases, such as hepatitis, HIV, malaria, and tuberculosis, require microbiology/virology testing for both causative agent diagnosis and antimicrobial resistance detection [3]. Recent data shows that inappropriate requests, errors in patient/sample identification, inaccurate laboratory results, as well as delays in communication and inaccurate interpretation, may increase the risk of generating diagnostic errors, thus pinpointing the ever-increasing pivotal role of laboratory information in clinical reasoning and managed care on the one hand, and the compelling need to reduce the risk of errors throughout the entire testing process.[4]

2. Literature review

Laboratory diagnostics is commonly defined as a medical science that seeks to generate useful clinical information by quantifying the concentration, composition, or structure of numerous analytes in various biological fluids. The daily activity of laboratory services includes performing a variety of tests to generate qualitative, semi-quantitative, or, most commonly, data. These numbers (also known as "values") can then be transformed into useful medical information by clinical interpretation, a process that develops through experience, practice, knowledge, and continuous critical analysis.[5]

Over the last 20 years, laboratory medicine has become increasingly important in clinical decision-making and patient management. Laboratory tests are critical for maintaining health, screening for diagnosis, and monitoring patients [6]. With the continuous development of more complex tests, medical practice will become increasingly reliant on laboratory medicine [7], and this process will be supported by the forthcoming translation into clinical practice of new insights from promising research areas such as genomics, transcriptomics, proteomics, and other "omics," particularly for early diagnosis and "personalised medicine" [8]. However, laboratory tests and data are only useful when they are translated into clinical information that physicians can use to improve clinical

reasoning and patient management . The effectiveness of laboratory tests must thus be evaluated and measured in terms of the clinical benefit they provide in terms of an improved diagnostic process and/or therapeutic strategy, with the ultimate goal of maximising overall health outcomes.[9]

Laboratory medicine is crucial in modern healthcare systems as it optimises patient flow, harmonises procedures before and after analysis, improves harmonisation, and reduces unnecessary testing. Nonetheless, recent changes in the nature of laboratory services, facilitated by innovation and the introduction of more complex tests in emerging diagnostic fields, more advanced diagnostics, and other "internal" and "external" drivers, will serve as a paradigm for current scenarios. The future of laboratory professionals remains uncertain, and it appears that the role and image of laboratory scientists and professionals will evolve.[10]

The transition from manual techniques to early automation, such as the autoanalyser, and now to fully integrated robotic computerised systems has been rapid, resulting in an exponential increase in laboratory efficiency and productivity.[11]

In response to this pressure, laboratory networks with centralisation were implemented, resulting in a hub and spoke model. Such a model introduces its own complications, such as the need to distribute staff based on demand and workflow, as well as logistical challenges associated with sample movement and tracking.[12]

One of the challenges of medical progress is the tendency to maintain previous testing strategies rather than removing obsolete tests from the clinical repertoire. [13]

Laboratory medicine may take the lead in developing new tests. Cardiac biomarker measurements have played an important role in defining diagnosis, management strategies, and, more recently, treatment options in patients with ischaemic heart disease. Aspartate transaminase was the first independent biomarker that enabled a definitive diagnosis of myocardial infarction. [14]

Cardiac troponin is another interesting topic. The conclusions of a recently published review on alternative causes for elevated cardiac troponin levels after acute coronary syndromes have been ruled out highlight that "while troponin is a sensitive biomarker to 'rule out' non-ST segment elevation myocardial infarction, it is less useful to 'rule in' this event because it is not specific for acute coronary syndromes" [15]. This contradicts evidence that cardiac troponin is effective in diagnosing myocardial damage because of its high positive predictive value, allowing cardiologists and emergency physicians to correctly identify "acute myocardial infarction" in approximately 30% of ST-negative patients with chest pain and clinical evidence of ischemia.[16]

Laboratory medicine must be adaptable to new treatment strategies that employ novel testing methods. The provision of testing may present interesting logistical challenges that necessitate either service reorganisation or the implementation of novel technologies. The use of selective catheterization to localise parathyroid tumours is an example of where the ability to measure

parathormone effectively in real time is required to support surgical exploration of the neck[17]. Similarly, the increasing use of contrast-based cross-sectional imaging (computed tomography and magnetic resonance imaging) has necessitated a pre-imaging assessment of renal function. Many patients arrive for imaging without first being investigated. This issue can be addressed by implementing point-of-care creatinine measurement in the imaging department.[18]

Epigenetic modifications across the genome are orchestrated phenomena that influence the transcriptional output of the genetic code. In this sense, identifying the abnormal changes in the epigenetic landscape associated with human disease and the factors promoting such alterations provides the potential for new biomarkers that contribute to clinical decisions. [19]

Currently, laboratory technicians and instrument manufacturer service personnel are in charge of maintaining this analytical part. As a result, refocusing on the profession's core competencies, namely test selection and interpretation, is required to improve the diagnostic component of patient care in terms of quality, patient safety, efficiency, and effectiveness. Furthermore, this strategy will keep the laboratory specialist's profession from becoming obsolete in the near future, reducing the quality of patient care.[20]

3. Methodology

Although the definition of "normal" values for common laboratory tests is widely used in diagnosis, treatment, and managed care, there are few systematic analyses of baseline variation across demographically different population strata (e.g., race, ancestry, gender, sex, age, and socioeconomic status).

3.1 Conserved gene targets can be identified through sequencing.

The amplification and sequencing of universal gene targets is a technology that allows for the timely identification of difficult-to-identify bacteria. Among the various investigated gene targets, 16S rRNA gene sequencing is the most commonly used for bacterial identification in clinical microbiology laboratories. The difference between the 16S rRNA gene sequences of the bacterium and closely related species is critical for successfully identifying a bacterium to the species level.[21]

The identification of antibiotic resistance patterns quickly became an important aspect of infection management. As new antibiotics are introduced, resistance testing is necessary to track the emergence of resistance patterns.[22]

The identification of specific tumour subtypes caused by specific oncogene mutations has led to the development of targeted therapies. The laboratory's role is to identify susceptible tumour types so that these novel therapies can be used more effectively.

3.2 integrated diagnostics in cancer

Pathology has been at the heart of cancer diagnosis for decades, as it is the only branch of diagnostic medicine capable of identifying malignant disease, defining the type of cancer, the stage, and even the potential therapeutic vulnerability . The numerous advances in our understanding of cancer biology (e.g., the discovery of genetic mutations and epigenetic determinants that drive cancer growth), combined with notable technological advances [23]

3.3 Integrated diagnostics for infectious diseases

Respiratory infections, particularly pneumonia, are the most common causes of systemic disease and account for the greatest number of deaths.

At least two major reasons support the need for an accurate and timely sepsis diagnosis. The first, and the most obvious, is straightforwardly summarized in the "It's About TIME" mantra of the Sepsis alliance, which high- lights that the prognosis of this condition is essen- tially time-dependent [24]

3.4 Virus Isolation and Identification.

Molecular diagnosis is more sensitive and faster than traditional virus isolation methods because it amplifies nucleic acid from inactivated viruses. However, the specimens and RNA must be handled with care to prevent RNA degradation.

Nested RT-PCR, using primers at different regions of the dengue viral genome, has been developed for diagnosing virus in clinical samples. [25]

3.5 Detecting the Virus Antigen

In addition to using PBMC, an amplified fluorogenic ELISA (F-ELISA) was developed to increase the sensitivity to detect virus antigen in serum samples.

3.6 Circulating cell-free DNA.

Circulating cell-free DNA (cfDNA) has been detected in cancer, autoimmune diseases, infectious diseases, stroke, sepsis, trauma, and pregnancy. [26]

4. Results

In routine clinical practice, during the process of diagnosis and therapy, there are several parameters that must be considered as a reliable biomarker, such as high sensitivity, specificity, and positive predictive value (PPV).

Furthermore, new technologies are increasingly being used in clinical laboratories, and nucleic acids can now be analysed in a wide range of biospecimens (e.g., urine, plasma, serum, milk, fresh and frozen tissue, formalin-fixed paraffin-embedded (FFPE), etc.). As a result, these epigenetic

biomarkers have obvious clinical applications in diagnosis, prognosis, disease progression monitoring, and clinical decision-making.

RT-qPCR has emerged as one of the most important tools for molecular diagnostics in clinical laboratories. As a result, this is one of the most widely available tools for analysing miRNAs in various types of biospecimens during clinical diagnosis.

In healthy subjects, the amount of cfDNA is typically very low (less than 5 ng/ml of plasma), but it can increase by up to 8-10 times in those with a neoplastic disease. Because of its small size and fragmentation, isolating and quantifying cfDNA from body fluids is difficult. Furthermore, the extraction and purification stage is critical for the development of reproducible, standardised methods for cfDNA isolation, including quality controls to measure extraction efficiency, fragment size bias, and yield.

Laboratory medicine facilitates patient-physician interactions by providing relevant data, increasing the likelihood of making the best decisions for the individual's optimum care. It includes the traditional fields of clinical chemistry, toxicology, haematology, immunology, microbiology (including serology and virology), anatomical pathology, cytology, molecular pathology, and cytogenetics.

5. Discussion

Clinical laboratories are not only testing services, but also knowledge services that make use of all available communication channels; they provide more than just assay results; they also provide knowledge and education. Laboratory tests cannot be externalised if laboratory professionals are to function as an integral part of the healthcare system, strictly cooperating with clinicians and effectively demonstrating and establishing their status in their respective communities.

The future of laboratory medicine appears bright. Innovative biomarkers and advances in molecular diagnostics for identifying risk factors, early diagnosis, treatment guidance, and treatment personalisation have significantly contributed to the revolutionization of modern medicine, and will continue to change and improve the quality of care for individual patients as well as the general population. [27]

6. Conclusions

Clinical laboratories are not only testing services, but also knowledge services that make use of all available communication channels; they provide more than just assay results; they also provide knowledge and education. Laboratory tests cannot be externalised if laboratory professionals are to act as an integral part of the healthcare system, strictly cooperating with clinicians and effectively demonstrating strategy and status within their local communities.[28]

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