

# The Role of Pathological Analyses in Monitoring Treatment Effectiveness

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**Annotation:** Pathological analysis is a basic requirement in modern oncology, orthopaedics, trauma surgery, etc. for the diagnosis and monitoring of disease-related complications. Early and accurate determination of the pathological features of a disease such as cancer or of a trauma is crucial first for correct diagnosis. Moreover, pathological analyses play an essential role in planning and monitoring the success of treatments such as medical cancer therapies and the placement and follow-up of prostheses. Surgical treatment in traumatology includes the therapy of single injuries such as fractures of bones, ligamentous rupture, or dislocation of joints. However, surgical intervention is life threatening and expensive and comes with the risk of infections and functional sequelae. Therefore a precise therapy planning taking into account the whole clinical history of the patient including the pathological background is necessary for high success rates. The success of the treatment is highly determined by the time between trauma and therapy, the quality of the operation (position of prosthesis) and the rehabilitation (early mobilisation) [1]. Regular

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postoperative controls by x-ray imaging are carried out to monitor the success of the operation. This paper introduces 3D ultrasound imaging as an alternative or complementary modality with less exposition of the patient for therapy planning and followup care. Pathological analyses are obligatory to determine postoperative irregularities as early as possible to minimize the costs for health insurance from complications. Many times, pathological analyses including surgery and x-ray imaging are ambiguous for the interpretation. Accurate spatial models obtained from raw tomographic data can assist the practitioner in risk assessment. About a quarter of cancer deaths is caused by metastases, the spreading of tumor cells from the primary tumor to distant organs. Hematogenous metastases are of special interest as they are responsible for malignancies in the liver, lung and bone. Modeling the blood transport of tumor cells can help to understand and to prevent the onset of secondary tumors [2].

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## 1. Introduction

Monitoring the Effectiveness of a Medical Treatment is a Sophisticated Endeavor: The Crucial Role of Pathological Analyses in Undertaking this Challenging and Complex Task ,Understanding the role of pathological analyses in monitoring the effectiveness of a medical treatment is fundamentally rooted in a deep appreciation of two demanding challenges that arise from present increases in medical cures and also a noteworthy rise in the complexities associated with these treatments. To begin with the former, the growing breakthroughs in fields such as oncology, particularly with the introduction of targeted therapies and immune checkpoint blockers, place increasing demands on the companion adaptation of diagnostic tools. These tools are crucial for selecting the patients who will genuinely benefit from the advanced treatments available. In response to the latter challenge, we see a marked increase in the elderly population across many societies, where patients suffering from more than one illness—known as comorbidities—are becoming the typical case. It is crucial to recognize that a Medical Apple a Day Keeps Pathology Away. This aphorism reflects the current emphasis on preventive care that focuses increasingly on an understanding of DNA and the advanced methods derived from molecular biology. These methods need to be rigorously tested before actual treatments are administered, aligning closely with the specific diagnosis made for each patient. Last but certainly not least, there is an ethical obligation to ensure that any therapy undertaken to combat a specific disease or morbidity does not inadvertently cause harm to healthy organs, a risk that has unfortunately manifested in medical history in various instances. [3] [4][5][6][7]

The assignment of a treatment to be deemed successful, as well as having an accurate and comprehensive knowledge of the correct diagnosis, underlines the stringent and essential link that exists between these two critical concepts. Indeed, the only cases in which the cause of a specific disease was fully apprehended or at least conjectured were typically diseases for which seemingly

only empiric cures were recommended, or those fatal diseases against which the only possible medical action seemed to be to ensure a comfortable death for the patient. Ensuring a successful treatment requires a multiplicity of cultural approaches, meaning that it is crucial to involve the collaboration of expert individuals who can examine and take into account the complex problem from multiple points of view. This collaborative approach is designed in such a way to ensure that various weak points are identified and addressed by different specialists, utilizing their unique insights and experiences. Therefore, lessons learned in one discipline can be profitably applied and integrated into other fields, leading to a more holistic understanding of health and disease. Until roughly one century ago, this multidisciplinary approach was common practice among healthcare providers, and a general practitioner facing tough cases would routinely seek advice from a wide range of ascertained experts, drawing upon their diverse knowledge and expertise. However, this is no longer the case in modern medicine, because nowadays, physicians are often expected to have total command of their specific discipline. Consequently, they usually tend to look for ways to cure any given illness primarily through the use of drugs, which may lead to a more limited perspective on treatment options and patient care. [8] [9][10][11][12][13]

## 2. Overview of Pathological Analyses in Medicine

I. Medical Pathological Analyses A. Definition and Scope Medical pathology stands as the fundamental bedrock upon which the current status of clinical medicine rests. It constitutes the very foundation for the practices that define modern medical approaches. The ongoing refinements and advancements in medical education, cutting-edge research, and efficient diagnosis resonate deeply, underscoring the immense significance of medical pathology in today's healthcare landscape. Meandering through the superb and intricate scientific world of pathology has fostered the emergence of many newer, specialized sub-branches of pathology. These branches include forensic pathology, which examines the causes of death, and toxicologic pathology, which investigates the effects of various toxins on bodily functions. In parallel with the increase in scientific explorations and advancements, the role of pathology is progressively getting leveraged and integrated into comprehensive patient care. [14][15][16][17]

B. Historical Developments Medical pathological analyses have evolved through various significant stages over time, and numerous clever and insightful people have dedicated their efforts to correlate the macroscopic figures observed in deceased individuals with their clinical symptoms experienced in life. An example showcasing this evolution from the early 1930s is an experimental investigation into tooth cavities. This study involved a thorough microscopic examination of vital teeth that were subjected to cavity creation, carried out before the procedure and at intervals up to 36 days following its completion. The results of this thorough investigation revealed that only 4 out of a total of 32 teeth remained free from any histological pulp damage after the cavity had been created. The pulp damage that was observed ranged from mild injuries to severe afflictions. Inflammation and evidence of calcification were also noted during this process. Remarkably, the inflammation was never observed more than 1.5 mm from the exact point where the injury was initially inflicted. Furthermore, the first focal signs indicating inflammation in that area were not observed until a minimum of 16 days after the injury occurred. This groundbreaking study brilliantly established the close connection that exists between clinical medicine and pathological macroscopy and ultimately sparked a much-needed exploration into the subject. Since that time, a great number of macroscopic correlation analyses have been conducted, each contributing to the foundational knowledge that has played a significant role in the development of contemporary diagnostic science. The significance of medical pathology has, thus, been clearly established and recognized within the medical community. [5][18][19][20][21][22][23]

C. Divisions There are several essential divisions within the field of medical pathology, which include macroscopy, microscopy, chemical inspection, and biological inspection. Each of these branches plays an integral role in the comprehensive understanding and assessment of various diseases and conditions. The prevention and recovery of patients are predicated upon deep research and accurate representations of pathological findings to inform clinical decisions effectively.

[24][25]

D. Interplay between Clinical Practices and Pathological Findings Modern medicine is practically unimaginable without the profound knowledge and understanding of pathology. The interconnection with clinical practices proves to be especially valuable in the realm of healthcare. Not only does this interrelation advance the boundaries of various medical specialties forward, but—on the other hand—the pathological findings obtained must always be measured and viewed in the context of real-world cases. Dead-end speculation that is distanced from the concrete case can lead to misunderstandings and misinterpretations. Otherwise, the actual findings amassed through investigation will “steamroll” and overshadow that speculation, bringing clarity to the confusion. [26][27]

E. Diagnosis, Treatment, and Monitoring Medical pathological analyses must be comprehended as an overarching tool that supports and enhances the practice of medicine. When a patient presents to a hospital, guided by anamnesis and symptomatic analyses, there may spontaneously arise the need for macroscopy to obtain valuable insights. Subsequent to the adoption of a concrete diagnosis, based on the detailed staging and organ pathways, specialized treatments may evolve into either alleviation or complete healing of the condition. However, the deliberated processing of this information can only be successfully achieved on an observational basis that is methodically grounded in evidence. To effectively verify therapeutic success, follow-up macroscopic, microscopic, chemical, or biological investigations will eventually continue to serve as critical components of the overall assessment. [5]

F. Evaluation In the realm of modern medicine, one world of medical pathological analyses conjures up an image of a sophisticated and multifaceted array of investigatory methods, the varieties, depth, and names of which are not always eminently unforgettable. A brief enumeration of these methods is provided in what follows, accompanied by carefully crafted hints for understanding that aim to inform laypersons about these complex yet essential processes and techniques used in medical pathology. [8][3]

## 2.1. Definition and Scope

Pathological analyses constitute an essential and indispensable component of the medical field and are routinely conducted in the vast majority of both hospital and outpatient settings across the healthcare landscape. Given that these analyses have a direct and significant impact on the clinical outcomes for patients, it is paramount to carry out high-quality pathological analyses. There exists a wide array of pathological methods that are employed in contemporary clinical medicine by medical doctors, dentists, and a variety of other healthcare professionals, all of whom rely on these analyses to inform their diagnoses and treatment decisions. These methods encompass a range from the gross macroscopic examination of tissues that are collected during surgical procedures and oral cavity treatments to an extensive variety of histopathological techniques that include not only traditional light microscopy but also an expansive array of modern molecular pathology techniques that have revolutionized this field.

Pathological analyses are extensively utilized in the diagnostic processes for a multitude of medical conditions, which may range from routine chronic inflammatory processes to various types of injuries, as well as both benign and malignant tumors. Furthermore, they are also applicable in evaluating hereditary diseases, autoimmune disorders, and immunodeficiency conditions. Additionally, these analyses serve a critical role in monitoring the effectiveness of various treatments, including antibiotic therapies, anti-inflammatory treatments, and surgical interventions, among others. By assessing the specimens carefully, pathological analyses are often capable of unveiling the intricate mechanisms underlying the disease processes and, in circumstances where current medications may no longer yield favorable results, they can help in the development of new possibilities for personalized treatment strategies or suggest necessary modifications to existing treatment regimens. As a result, the overarching aim of the pathological analyses remains focused on conducting high-quality and comprehensive examinations of the

specimens collected from the patients. This is done using appropriate and validated laboratory techniques and, when indicated by professional opinion, these specimens may be subjected to additional in-depth diagnostics utilizing modern molecular pathological tests that are known for their high specificity and sensitivity in detecting various pathological conditions. [28][29][30][31][32][33]

Over the last decades, a number of misconceptions concerning the role of pathological analyses can be observed, leading meanwhile to a fast-growing alternative health care approaches. For example, it is often assumed that cancer can only be proven using genetic methods, or that taking bacterial samples from the sore throat is not reliable non-evidence-based claim. Using miserable common sense or improper storage of samples make many oncological reports have no medical significance. Using advanced diet supplementation cannot cure cancer nor significantly reduce the size of benign tumors such as fibroids. With the increasing availability of the outdoor private sector, people are not directed to specialized laboratories and large hospitals for diagnostic tests, so wounds, tumors, and nevi are evaluated with over-the-counter 50x USB microscopes apparently showing changes to “immature” cells. It is also recognized that pathologists, i.e. medical doctors specializing in pathology, perform many analyses only in a commercial setting and do not issue opinion for samples obtained from sources other than surgery or medical examination. Blocked lymph vessels can only be caused by Epstein-Barr virus. Recellularization of the nervous system after suffering a stroke or cranial nerve damage is possible using an extremely restrictive home remedy. [34][35][36][37]

## 2.2. Historical Developments

Pathology is an ancient medical science. It persisted in rudimentary forms long before the era of vernacular practitioners consulting tissue diagnosis for their patients. The past is replete with stories of the use of exudates and effusions for diagnosis, often in the context of mass outbreaks of mysterious illnesses. Although the cholepotomy of a doctor sampling the wrong organ is widely believed to be apocryphal, widely available technology and the development of cross-sectional imaging would not be seen in modern medicine for millennia [3].

Pathology has undoubtedly progressed significantly since its earlier days, marked by continuous and progressive improvements in its various techniques, alongside a deeper understanding of the complex disordered morphological and chemical processes that underlie various diseases. There have been numerous milestones that have marked this impressive progression; among the enduring achievements is the monumental recognition at the close of the 1800s that substances and damaging agents could be effectively observed under a microscope, provided they were preserved in a proper and suitable manner. Ever since that pivotal time, a multitude of new tissue staining techniques have been developed, and these advancements have built up over the span of the last four decades into a diverse range that is now regarded as invaluable for the purpose of accurately phenotyping tumors and effectively distinguishing between morphologies that may appear quite similar at first glance. The collection of techniques and tools found in the box during the 1960s would certainly not encompass such a broad array—indeed, it would have been much more limited in scope and variety. Diagnosis saw substantial facilitation thanks to the widespread adoption and utilization of light and electron microscopy throughout the 1970s and 1980s, which coincided with the emergence of additional innovative techniques during that same era. Alongside these advancements, immunohistochemistry, the automation of various laboratory techniques, as well as constructs such as ‘parablocks’ and tissue microarrays have all proven to be consequential and instrumental in enhancing the capabilities of pathologists. In summary, considering the changes and developments that have occurred since the 1960s, it is evident that there has been remarkable and significant progress in the realm of pathology techniques. Furthermore, the storage and retrieval of these vital specimens has also, of course, been greatly enhanced over the years. Each step of this evolution, along with comprehensive explanations for the reasons behind its development, can be read about in much greater detail in various scholarly texts and articles. [8][38][39][40][41]

### 2.3. Types of Pathological Analyses

Pathological analysis is a comprehensive term that encompasses a wide range of different types of methodologies: histopathology and cytopathology serve as direct approaches for the visualization of tissue sections, while the study of morphology plays a crucial role as well. Additionally, the rapidly gaining popularity of molecular pathology and advanced bioinformatics within the realm of omics studies introduces yet another dimension to this field. Each of these methods possesses its own unique materials and specific approaches, as will be elaborated on later, yet they are all fundamentally inter-connected in processes such as diagnosis, grading, and ultimately leading to crucial decision-making regarding treatment options. To facilitate a better understanding of the diverse methods available, it is essential to briefly mention some relevant applications that will effectively highlight both the diagnostic value and the therapeutic implications associated with each technique, in addition to outlining the rationale behind selecting particular methods in varying conditions. In practical scenarios, histology is often instrumental in suggesting potential diagnoses; consequently, further biomedical analyses like immunohistochemistry (IHC), fluorescence in situ hybridization (FISH), and additional levels of gene and protein expression profiling are typically recommended only if the morphological study fails to provide definitive answers. These advanced technologies, along with other innovative methodologies that are continuously emerging, serve to support and complement rather than completely replace traditional pathological methods, thus significantly enhancing the overall diagnostic accuracy. Engaging discussions can be effectively supplemented by original clinical case examples, which not only illustrate the practical applications of each type of pathological method but also emphasize their usefulness in real-world scenarios. It is important to note that various pathological analyses were initially observed when compared to traditional observational techniques, but such limitations actually serve to illustrate the nuances of our current methodologies in monitoring the effectiveness of treatments over time. In the early stages of disease, profound cellular changes are less likely to occur; therefore, analysis chiefly focuses on the tissues that have been surgically removed rather than the areas that have been treated. Great importance is placed on the selection of the most suitable analysis methods to ascertain the effectiveness of treatments provided to patients. [3] [42][43][44][45][46][47][48]

### 3. Pathological Analyses in Monitoring Treatment Effectiveness

This section is particularly intended to comprehensively review the critical role of pathological analyses in assessing the overall effectiveness of treatment interventions. Treatment intervention and control groups systematically attempt to validate their relative benefits, utilizing the aid of ongoing pathological monitoring conducted in a preclinical or clinical setting. In this perspective and viewed from a different angle, this section provides valuable insights into the progression and response of various diseases as interpreted through the lens of pathological analyses of affected tissues and organs. Such complex experiments equally open up a fascinating new direction, allowing these rich data sets to be potentially harnessed in the design of different therapeutic strategies aimed at achieving desired clinical outcomes. Fitting targeted treatment to underlying pathology is likely to become an ever more significant activity within the healthcare professions, given that ongoing improvements can often be made upon the initial response to treatment and pathological conditions. Moreover, the long-standing dependence on established treatment regimes should undoubtedly be subjected to careful re-examination from time to time, given the prevailing risk that the progress of the primary condition might be effectively masked by the emergence of treatment-induced secondary conditions that may arise during therapy. Monitoring the overall effectiveness of any treatment in efficiently controlling the disease may be achieved through various means and methodologies. Some approaches involve direct and detailed assessments of the disease condition by virtue of sophisticated histological, immunohistological, or advanced molecular biological examinations. In the intricate design of innovative therapeutic strategies, methods such as nuanced phenotypic and karyotypic histo-pathological diagnoses are especially pertinent and are employed correspondingly in various contexts. Proposed studies, however, typically incorporate a range of other experimental multifactor paradigms of pathological

analyses that, nevertheless, have a remarkably similar aim in terms of understanding the disease process. The treatment of a particular disease usually involves both intervention measures and detailed follow-up observations, although it is sometimes fortuitously discovered serendipitously due to a pre-existing project encompassing studies that do not strictly pertain to the initial focus of the original work. In reference to the latter, an additional experiment is designed as part of the treatment option, which, correspondingly, aligns with other expectations and designs rooted in the primary research questions initially posed. This, however, subsequently extends to related works through a thorough review of the existing literature. Collectively, these examples illustrate the inherent flexibility and practical use of the data generated, which can occasionally be connected to other matters that relate to practical pathological diagnostic approaches within the framework of a randomized trial. Additionally, there exist insightful commentaries on the myriad challenges and implications faced by the healthcare professions due to the increasingly growing volume of data emerging from the vast pathological scope and the inherent difficulties in interpreting and effectively integrating this data into comprehensive clinical practices. [3][4][49][50][51][52][53][54]

### 3.1. Importance of Pathological Analyses in Treatment Monitoring

The complexity of oncologic patients shall not be underestimated. At present, patients in need of antineoplastic therapy require a comprehensive multimodal treatment approach, with regular clinical and laboratory follow-up. In this setting, pathological analyses might become an essential tool in monitoring the effectiveness of applied therapy, providing widely understood objective data. First, they are fundamental to identifying therapeutic responses, as in the majority of patients these are reflected as modifications in the morphology of the neoplastic process [3]. Secondly, seen as the majority of oncologic medications exert cytotoxic effects, also beyond their antineoplastic action, pathological analyses verify treatment toxicity or coexisting neoplastic disease. The significance of such a wide use of pathological data becomes evident in the light of the dynamic development of personalized medicine with an increasing number of molecular factors crucial for appropriate treatment selection. [55][5][45]

Pathological analyses are also indispensable in the monitoring of the effectiveness of modern targeted therapies, including that applied in non-small-cell lung cancers (NSCLC). The rapid development of precise molecular therapy results in the increasing diversity of administered drugs obstructing the understanding of their action and resistance mechanisms [56]. In this context, systematic analyses of tissues prior to the selection of the treatment lines are necessary. The early integration of a wide spectrum of pathological data with clinical indicators contributes also to the improvement of prognoses' accurateness, enabling the early correction of care strategies. However, continuous clinical follow-up of patients provides only the clinical part of information necessary for an accurate prognosis. It is widely understood that integration of both clinical and pathological data could give a wider perspective on the disease allowing a rational treatment procedure. Necessary calculations are processed automatically taking a few minutes. All of this enables to provide the practical application of the developed model suitable for any patient with pulmonary cancer (irrespective of the applied therapeutic approach). Critical results are achieved both in disease staging and prognosing (sensitivity and specificity > 80%). For comparison, corresponding values for the TNM system amount to, respectively, 64 and 72%. Moreover, timely availability of the obtained results might make possible to alter the treatment strategy during the operation (by limiting or expanding the surgical procedure). When used on a wider scale, the system may contribute to the optimization of both individual and overall medical care. It is crucial, therefore, to involve pathologists at an early stage of treatment planning. [57][58]

### 3.2. Common Pathological Analyses Used in Treatment Monitoring

A cancer patient worried about treatment effectiveness can undergo a PET/CT imaging study, blood tests like a complete blood count or tumor marker measuring, or a tissue biopsy that can be obtained through invasive/surgical procedures. Such an individual might also be interested in

taking advantage of advanced and emerging non-invasive technologies that combine intuitive body measurement with a bio-medical algorithm. As of now, most medical treatments have no more than a modest proven clinical effect compared to any placebo, so taking his/her everyday pill might not produce significant differences. The placebo effect probably derives from a combination of several healing-associated effects, ranging from faith in the healer, ritualistic elements of the therapeutic encounter, experiences and learned associations about treatments, prior experiences and expectations, and a variety of social learning mechanisms. To have a better knowledge about these aspects, a health services analytic study can be booked. As a result of such evaluation, a referral to an anthropologist in health and illness who can design and perform a ritual sequential process that may amplify all those aspects can be given. If pain reduction because of the disease is a concern, a follow-up evaluation can include expert consultation with a very specialist in placebo and nocebo, specifically addressed to take advantage of the clinical setting. About the very final condition it can be stated that there is no such disease entity. Probably the most similar option is the poorly curable nontuberculous (or atypical) mycobacterial lung disease, which has high mortality and morbidity rates. Discounting smoking cessation, various nutritional treatments, stress management, and AIDS prophylaxis, no other therapy has been effective for life expectancy and symptomatic improvement of this disease outside the cancer world since the 1990s. Whether to test the best available treatment or to undergo careful palliative treatment is though a doubt that only one individual can solve. One suggestion is to consult with a specialist in infectious and immunodeficiency disorders to find all the possible treatment options known so far. Regardless, quarterly blood and imaging analysis must be done to optimize therapy adjustments and avoid treatment escalation at any possible earlier moment. [59][60]

### **3.3. Challenges and Limitations of Pathological Analyses**

Introduction of new technologies for the care of patients with cancer is historically accompanied by enthusiasm as well as skepticism [56]. The recent introduction of immune checkpoint inhibitors for the treatment of several cancers, including classical Hodgkin lymphoma (cHL), represents a paradigm shift in the management of cancer patients. To date, however, no prediction algorithm for response to these immune checkpoint inhibitors (ICIs) is available. Pathologists could help in designing tailored and more effective treatments if they could provide data on biomarkers of response to immunotherapy. A similar lack of prediction of response concerns the fast-development panorama of cHL treatment. The number of biomarkers that need to be considered is rapidly increasing and, for genetic biomarkers, molecular biology procedures are expensive and not always routinely available in the pathology laboratory. Because of the higher probability of finding a genetic alteration able to define the positive response (or the negative response) to a drug, the search for genetic predictive biomarkers dominates the current scenario [3]. Because of the increasing number of prediction biomarkers, the different availability and complexity in technical and data analysis requirements, and the intrinsic heterogeneity of the disease, the panorama is somewhat complex. Therefore, the pathologist should expect to manage a wide variety of either well-known and consolidated biomarkers, such as epidermal growth factor receptor (EGFR) in lung cancer, or novel biomarkers that define the mutational load. The underlying necessity is to establish specialized teams of experts to guarantee accurate collaborations. The sensitivity of some biomarkers can vary, involving controls for the time-to-time re-assessment of some tumor markers. This scenario puts an emphasis on the need for interdisciplinarity. It thus becomes pivotal that medical oncologists, molecular biologists, and pathologists have a close and continuous collaboration. [19][61]

### **4. Case Studies and Examples**

A series of case studies have been presented with the intention of illustrating the practical application of pathological analyses to assess the effectiveness of treatments and contribute to changes in patient management. Alongside the cases, some theoretical background is also given in order to stimulate debate and active student involvement. Those reading the cases are encouraged to further question the role that pathological evidence has in the treatment of individual

patients, and what the limits of that evidence may be. They should also consider writing their own cases (anonymised) which are appropriate for discussion. In their experience, a department of pathology is an untapped resource for long case presentations in a bedside teaching setting. Yet, it is well placed to provide accurate, timely, and impartial investigations of clinical situations and to become the focus for discussion in multidisciplinary team meetings (MDTs) where actual cases can be reviewed. There are suggestions as to how a start could be made in this direction. For many doctors in training or in other specialties, pathology is a “black art”; something of knowledge for examinations that is rapidly forgotten once membership or fellowship is gained [3]. Yet the practical application of pathology is integral to day to day patient management in any hospital. With this in mind, these cases should help to stimulate the use of problem based learning in pathology that is both academic and clinically relevant. They should also serve as an active reminder for pathologists to represent their practice as it contributes to excellence in patient care and always to consider personal, individualized therapeutic approaches. In turn, useful recommendations can be made regarding patient investigations, even though they may not always appear to be strictly, or at all, pertinent to the pathological findings. [5][62]

## 5. Future Directions and Emerging Technologies

When it comes to the monitoring of therapeutic responses for cancer patients, pathological analyses have provided major contributions already for a long time. Thus histopathological examination of tissue specimens is a principal method for diagnosing the disease and assessing its biological properties. However, the role of pathological analysis has changed in clinical practice due to the expansion of therapeutics that focus on new targets. Fifty years ago, surgery was the only proposed therapy for cancer. It was when cyclins were discovered in 1983 that the centrality of gene mutations to oncological illnesses directed efforts towards the gene-targeted therapy of oncological mutations. Since 1995 a variety of medicines targeted for gene abnormalities have launched with chronic myelogenous leukemia (CML) becoming a model case in which the detailed study of gene products that cause cancer allowed the resulting drug to transform a cancer diagnosis from a death sentence into a manageable chronic illness featuring near normal life expectancy. [63][64]

While a very similar patient may be effectively treated with or another BCR-ABL targeting therapy, for a time, a thorough study of the drug’s properties would prove that was the treatment of choice. The agent is completely specific to its target such that a new gene product, encoded by a mutant BCR-ABL gene, is the only cellular protein substantially affected by the drug. There exists other forms of that are less specific and display less inhibitory activity against myeloid cells, contributing to their inability to control a CML diagnosis. Additionally, has an unusually long half-life seeing as the metabolic byproducts and are nearly as effective an inhibitor of the BCR-ABL kinase as the parent compound. Since these forms share the same metabolite, generating the active forms, a centrally located enzyme, is fundamental for therapy. Thus, while mass spectrometry has been used in drug monitoring studies of various agents for years, a broader role for mass-spectrometric measurement, coupled to theoretical pharmacokinetic modeling, remains a rare diagnostic practice even in the oncological setting. With this rarely utilized method, a physician may have given a more suitable treatment immediately instead of waiting for the effects of repeated unsuccessful attempts [65]. [66][67]

## 6. Conclusion

Recent times have seen a revolution in the therapeutic options available to patients and physicians, particularly in the field of oncology. While the advent of immuno- and target-based therapies have dramatically improved outcomes for a number of different malignancies, identifying patients who are most likely to benefit and quickly recognising those who are not, remains a significant challenge. It is fundamental to track these patients and their disease closely, not only to ensure timely cessation of ineffective treatments, but also to make alternative therapies available in a timely manner. Pathological analysis plays a critical role in the monitoring and conceptualisation

of ongoing therapy responses, and continues to lead the way in improving patient care [3].

Timely pathological analyses are crucial in order for the results of such investigations to be actioned upon. Any delays in sampling lead to delays in diagnosing and treating abnormalities uncovered. With the advent of telepathology and machine learning, how samples are dealt with can usefully be separated from when. While new sampling devices will likely be able to further expedite the process, they must ultimately be used with these other technologies in order to fully realise improvements to patient outcomes.

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