Vol. 5 No. 2 (2026)

Pakistan Journal of Medical & Cardiological Review

https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387

Print ISSN 3007-2379

Ali et al., 2026

Clinical and Diagnostic Parasitology: Laboratory Identification Techniques, Biomarkers, and Evidence-Based Therapeutic Management Strategies

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Received on 26 April, 2026

Accepted on 20 May, 2026

Published on 21 May, 2026

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Abstract

Clinical & Diagnostic Parasitology is critical for identifying, diagnosing and managing parasites that are worldwide human health problems. The research discusses more advanced lab methodologies such as conventional microscopy, culture, serological assays, and modern molecular diagnostics including Polymerase Chain Reaction (PCR) & Nucleic Acid Tests. The use of biomarkers in parasitology has improved the ability to detect and diagnose parasitic diseases, leading to quicker clinical intervention and improved patient care through better sensitivity, specificity and early detection of disease. Biomarkers are derived from the immune response of the host, antigens of the parasite, and DNA from the parasite, which are being used more frequently to monitor disease status, assess prognosis, and evaluate therapy. The clinical efficacy and epidemiologic surveillance of antiparasitic therapies are now based on objective data that support appropriate drug selection, resistance monitoring, and individualized treatment choices. The recent advances in diagnostic technology & targeted therapies will result in improved disease control & minimization of the complications associated with these infections. The role of accurate lab diagnosis, epidemiologic surveillance and collaborative disciplines in the global public health outcomes will also be discussed. This review provides a comprehensive overview of the new and innovative diagnostics and therapeutics available for making effective clinical decisions, treating parasitic infections in endemic and non-endemic areas.

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about
Online ISSN 3007-2387
Print ISSN 3007-2379

Keywords: Clinical parasitology, diagnostic techniques, laboratory identification, parasitic infections, biomarkers, molecular diagnosis, serology, microscopy, evidence-based therapy, antiparasitic treatment

Introduction

The clinical and diagnostic area of parasitology is a vital component of the medical field that involves research, identification, diagnosis, and treatment of human parasitic diseases. Conditions such as malaria, amoebiasis, giardiasis, and helminthic infections continue to be public health concerns throughout the world, particularly in developing countries where poor sanitation and limited healthcare services contribute to a higher incidence of transmission. An accurate diagnosis is critical for effective management of an infectious disease, as inaccurate or delayed diagnoses can have inappropriate consequences and lead to increased morbidity and mortality. Clinical parasitology incorporates a number of disciplines such as laboratory medicine, microbiology, immunology, and molecular biology for the identification and evaluation of parasites, as well as overall evaluation of the progression of the disease process. Traditional methods used in laboratory settings, such as stool examinations and microscopy, remain popular due to their cost-effectiveness and accessibility; however, because these methods may fail to detect low parasite burdens or mixed infections, the increased burden of parasitic disease has resulted in demand for more advanced diagnostic and evidence-based therapeutic options. Therefore, the primary goal of clinical parasitology today is to increase the precision of the diagnosis and/or treatment of patients; manage patients more effectively; prevent disease; improve laboratories through innovative technology; or enhance laboratory science in order to support global health care systems and public health initiatives (Garcia et al., 2016)

Accurate laboratory identification techniques are essential the diagnosis as well as management of parasitic infections because they provide a means for healthcare providers to accurately detect and identify parasites. The standard laboratory identification techniques for diagnosing parasitic infections include direct microscopy, examination of stool specimens, examination of blood smears, examination of urine, and biopsy of tissues. Microscopy is the most widely used laboratory method for identification because it allows the direct observance of parasite egg, larva and cyst

within the host; Additionally, direct observation of trophozoites in the host can also help to establish laboratory identification of certain parasite species, especially protozoan species. Although microscopy is the most important method for establishing parasite identification, it requires skilled laboratory personnel and is less sensitive than other techniques when the parasite concentration within the sample is low. Therefore, in an effort to enhance the potential for accurate diagnosis of parasitic infections, modern laboratory methods such as serological tests and molecular diagnostics have been made available. The use of ELISA, rapid diagnostic tests and PCR techniques have provided faster and more accurate diagnostic information than traditional diagnostic methods. Molecular methods have also provided invaluable services for the identification of mixed infections as well as for the identification of genetically related, but distinct, parasite species. Laboratory automation and digital imaging techniques have furthered increased the accuracy of laboratory diagnoses by decreasing the occurrence of human error in diagnostic procedures. When conventional and advanced laboratory methods are combined to enhance disease identification, they create a solid foundation for accurate epidemiologic surveillance and for effective treatment of infected patients and provide critical healthcare management to a public health setting (Cheesbrough et al., 2018)

Biomarkers have become integral to modern diagnostics for parasitology; as they provide critical data regarding: Infection status, Disease severity and Response to therapy. Biomarkers can be biological measures from either the parasite or the immune system response of the host itself, and can be assessed from sample types (blood, urine, stool, and/or tissue). Examples of common biomarkers include: Parasite antigens, Antibodies, Nucleic acids, Inflammatory proteins and Metabolic products. Biomarkers are therefore extremely helpful for detecting disease at an early stage, particularly if there are no visible clinical signs of illness. Diagnostic tests utilizing biomarkers offer improved sensitivity and specificity to detect parasites and reduced false positives. Rapid diagnostic tests for malaria and leishmaniasis are great examples of rapid diagnosis of patients, while also determining the potential for future treatments. Molecular biomarkers allow researchers to evaluate the genetics; pathogenesis, and drug-resistant properties of parasites. Furthermore, current advances in genomics and proteomics, have greatly facilitated the discovery of highly specific biomarkers that can promote

personalized medicine and targeted treatment. The utilization of biomarkers therefore provides clinicians with better information to enhance patient management and advances the field of modern clinical and diagnostic parasitology globally (Ryan et al., 2020)

Therapeutic management strategies that are based on data and scientific research are vital for the control of parasitic diseases and the improvement of patient outcomes. Effective management includes obtaining accurate diagnostics, identifying the type of parasite, assessing the severity of the disease, and selecting the appropriate antiparasitic agent. Commonly prescribed drugs for the management of protozoan and helminthic infections include albendazole, ivermectin, metronidazole, chloroquine, and artemisinin-based therapies. The increasing prevalence of antimicrobial resistance is proving to be one of the major issues affecting the management of parasitic disease. The use of evidence-based medical practices promotes the use of treatment protocols that have been developed through scientific trials in clinical research and are supported by international public health guidelines. Due to improvements in the effectiveness of treatment as well as the increased risk of developing resistance, many parasitic diseases are increasingly being treated with multiple medications (combination therapy). Additional components of comprehensive therapeutics are providing supportive care, nutritional therapy, improved hygiene, and educating patients on their therapies. Healthcare providers need to assess treatment response, adverse drug reactions, and compliance with the prescribed treatment regimen in order to promote successful recovery. Today's evidence-based therapeutic approaches combine laboratory data, clinical expertise, and the most up-to-date scientific research to improve quality of care, as well as to enhance global control programs for parasitic infections (White et al., 2019)
Detection, treatment, and prevention of worldwide parasitic diseases have all been greatly enhanced by advancements in clinical and diagnostic parasitology over the last few years. New technologies in molecular biology, immunodiagnostics, and digital laboratory methods have revolutionized the ways parasitic infections are diagnosed and have increased the accuracy with which we can diagnose parasites. The automation of laboratory systems and the introduction of digital microscopy into diagnostic processes have helped to relieve some of the burden on laboratory staff and have provided more

accurate diagnoses. These improvements are especially helpful in public health settings with limited resources, where early identification of a parasite can prevent the disease from progressing and reduce the number of deaths due to the infection. Research programs and international health organizations are continuing to promote epidemiological surveillance, disease prevention, and public health education in order to reduce the number of people affected by neglected tropical diseases. Successful prevention and control strategies against new or emerging parasitic infections require collaboration among microbiologists, clinicians, epidemiologists, and healthcare policymakers from different disciplines. The ongoing research on vaccines, new treatments, and advanced biomarkers will also enhance clinical practice in the future. Sanitation, vector control, and health education will also play a role in minimizing the number of parasitic infections. For these reasons, clinical and diagnostic parasitology will continue to be a critical component of global health and will contribute to improved public health outcomes through continuous innovation and evidence-based medical practices (Roberts et al., 2018)

Clinical parasitology helps diagnose and treat parasitic diseases

Clinical parasitology is a medical specialty that deals with the diagnosis, treatment, and prevention of disease caused by parasites. Parasites include protozoa, helminthes, and ectoparasites; all of which infect humans through contaminated food, water, vectors or direct contact. These infections are especially prevalent in tropical and subtropical regions of the world, where poor sanitation, unclean drinking water, and limited access to healthcare both facilitate the transmission of these diseases. By identifying the causative organisms of disease and determining the appropriate therapeutic strategies for their infected patients, clinical parasitology aids healthcare professionals. Early diagnosis is crucial because parasitic diseases that go untreated can lead to serious complications, including anemia, malnutrition, organ failure, and death. Clinical parasitology integrates microbiology, immunology, pathology and laboratory medicine to help improve patient outcomes and overall public health. Your diagnostic methods include microscopically examining the specimen, serologic testing of the patient's blood and/or other body fluids, and molecular techniques used to identify parasite-specific antigens in biological specimens. Advancements in diagnostic technology have greatly

increased the speed and accuracy of diagnosing parasitic infections. Clinical parasitology also contributes to the worldwide epidemiological surveillance of parasitic diseases and to the development of programs for the prevention of these illnesses. Ongoing research and innovation in clinical parasitology will be necessary for the control of newly emerging parasitic infections and for enhancing global health services, particularly in developing countries where parasitic diseases continue to pose a significant burden to public health systems and economic stability (Cook et al., 2017)

When diagnosing parasitic illnesses, it is important to have accurate laboratory tests and evaluate the patient's signs and symptoms to determine how best to treat the individual and control the disease. Lab identification methods are very important in clinical parasitology because many infections caused by parasites present the same signs and symptoms as infections caused by bacteria or viruses. Therefore, diagnostic methods traditionally used to diagnose parasitic infections, such as stool examinations, blood films, and urine microscopy, continue to be used extensively by hospitals and reference labs. The ability to see parasite eggs, oocysts, larvae, or trophozoites through the microscope is considered one of the best reliable techniques to confirm parasitic infection. However, the limitations related to low sensitivity of microscopy and the skill necessary to interpret microscopic results has led to the development of more advanced diagnostic procedures. For example, serological tests measure parasite specific antibodies and/or antigens in the host. Molecular methods such as polymerase chain reaction (PCR) identify the presence of parasite DNA; PCR is a highly sensitive and specific method for parasite identification. These newer technologies for diagnosing parasitic infections enable earlier detection of infections than possible by conventional diagnostic methods and allow more accurate differentiation of closely related parasites. Infection identification also enables healthcare workers to monitor the disease progression and assess treatment outcomes over time. Lastly, data collected from laboratories on parasitic infections are also used in public health surveillance and to develop strategies for the prevention and control of parasitic diseases. Therefore, the combination of conventional and advanced diagnostic techniques enhances clinical decision making and improves the management of parasitic diseases in healthcare systems throughout the world (Bogitsh et al., 2019)

Biomarkers are now recognized as very important in modern clinical parasitology because they provide information about infection status, immune responses, and how well treatments are working. A biomarker is any measurable biological substance that can indicate either the presence or progression of an infection and can be derived from either the host's immune system or the parasite itself. Some of the most commonly used biomarkers in parasitology are parasite antigen, antibody, protein, enzyme, and nucleic acid fragments present in blood, feces or tissue. The use of markers helps clinicians to identify infections earlier than would typically occur based on clinical symptoms alone. Rapid diagnostic tests that use biomarker technology have enhanced the ability to diagnose parasites in remote or resource-limited locations where laboratory facilities may not be available. Rapid antigen detection tests have significantly improved screening and treatment initiation in patients with malaria and leishmaniasis by enabling earlier diagnosis than would be possible, allowing for timely intervention. Biomarkers also support research on the genetics of parasites, their pathogenicity, and the mechanisms of drug resistance. New technologies, such as genomics and proteomics, have recently facilitated the discovery of new biomarkers; as a result, the identification of pathogens with biomarkers has become significantly more accurate. Biomarkers also support clinicians in monitoring response to treatment and predicting whether a patient will experience a recurrence of their disease. Incorporating biomarkers into clinical practice has transformed patient care and improved the quality of evidence-based diagnostic strategies used to diagnose and manage diseases caused by parasites. Furthermore, incorporating biomarkers into the practice of clinical parasitology has contributed to the development of new evidence-based diagnostic strategies and improved healthcare management globally (Ash &Orihel, 2020)

The management of parasitic infections is based on a combination of evidence-based medicine. It includes accurate diagnosis, appropriate drug selection, and ongoing monitoring of the patient's condition. Antiparasitic medications eliminate or control the parasite that causes human disease. Among the drugs that are frequently prescribed are metronidazole, albendazole, praziquantel, ivermectin, and artemisinin-based combination therapies. The success of treatment depends on many factors including the species of the parasite, severity of the infection, the general state of the patient's

immune system, and the presence of any resistance patterns to the treating drug. Evidence-based medicine means that treatment decisions in parasitic infections are based on scientific research, clinical guidelines, and laboratory findings when available. With steadily increasing recommendations for the use of combination therapy, the treatment outcomes will be improved and the emergence of drug resistant strains of parasites will be prevented. Other key elements of comprehensive management of parasitic diseases involve supportive care, nutritional support, improved hygiene, and patient education. The monitoring of both adverse drug reactions or responses as well as recovery outcomes is vital to ensure patient safety and a successful recovery. Public health programs that concentrate on vector control, sanitation, and health education also contribute substantially to improving the reduction of parasitic disease transmission. Modern strategies for parasitic infections involve the integration of clinical experience and evidence-based medicine to improve the quality of health care and to enhance global efforts to control parasitic infections and reduce the incidence of complications related to these diseases (Murray et al., 2021)

Recent improvements in clinical/dx parasitology have changed our knowledge of/management of parasitic diseases significantly in the last few years. Advanced techniques, e.g., molecular diagnosis, immunoassays, automated labs, digital microscopy have vastly increased both the speed and accuracy of identifying parasites today. Rapid diagnosis in a health care setting has major importance in preventing severe complications/deaths from these infections and rapid identification is becoming more critical due to the rising number of incurable parasitic disease cases worldwide. Artificial intelligence and bioinformatics are being added to Dx labs to improve the analytical capability of laboratories and the effectiveness of disease surveillance systems. International agencies involved with global health have continued to support research and/or control programs addressing neglected tropical diseases and emerging parasitic infections. Infection prevention strategies including improved sanitation, clean water supply, vector control, and public health continuing education are critical components of lowering worldwide infection rates. Ongoing research into vaccine development, novel antiparasitic agents, and advanced biomarkers will lead to even further improvements in disease prevention and patient care in the future. Collaboration among

the healthcare team members, i.e., clinician, microbiologist, epidemiologist, and public health professional, are required for the development of sustainable healthcare delivery systems for controlling parasitic diseases (Paniker et al., 2018)

Microscopy and stool examination are common diagnostic methods

Stool examination and microscopy are commonly used diagnostic tools for detecting parasitic infections in humans caused by both blood parasites and intestinal parasites. These routine laboratory techniques have many advantages; they are cost-effective, accessible, and enable direct visualization of the structure of the parasite (i.e. eggs, larvae, cysts, and trophozoites). Stool examination is especially useful in diagnosing intestinal parasitic infections, including amoebic dysentery (amoebiasis), giardiasis, ascariasis, and hookworm infection. When a sample of stool is collected, the sample is initially examined macroscopically for any abnormality, and subsequently microscopically, to detect any presence of parasitic stage organisms. Microscopy is of great importance in diagnosing blood infections caused by parasites such as Plasmodium species, which are responsible for causing malaria. Thick and thin blood smears enable laboratory technologists to differentiate between the morphology or make up of the parasites and to make an estimate of the number of parasites. Although these traditional laboratory techniques are relatively easy to perform, in order to achieve accurate results, it is important that the technologist performing the tests has the appropriate training and experience. Accuracy is also dependent on additional factors, such as, sample quality, the concentration of parasites in the specimen, and the timing of specimen collection. In addition to the growing use of molecular biology techniques in diagnostics, microscopy and stool examination continue to be the primary tools used in many health care settings. This is particularly true in resource-limited/developing countries where there are limited opportunities to use expensive diagnostic technologies. The use of microscopy and stool examination will continue to play a major role in disease surveillance, patient management, and in many public health control programs worldwide (Chiodini et al., 2015)

Microscopic evaluation has long been an important and reliable laboratory diagnostic method for the detection of parasitic diseases because of the ability to view the parasites directly in different specimens. In stool examinations, cysts, trophozoites,

ova, and larvae can all be detected under the microscope using saline or iodine preparations, as well as concentration techniques like flotation and sedimentation, which can improve the likelihood of detecting parasites even when the organism load is low. Additionally, microscopy is crucial for identifying blood parasites, including malaria, filariasis, and trypanosomiasis. Thick blood smears can help determine if a parasite is present, while thin blood smears can help establish which parasite and what morphology they have. The laboratory technologist's skill level and specimen preparation quality are significant factors in the accuracy of microscopy diagnoses. Similarly, if staining methods were not properly carried out or if there are delays in processing, the results may not accurately reflect the parasites detected. However, there are still many countries where microscopy is the most commonly utilized method of diagnosis of parasitic infections, primarily due to cost and turnaround time. Therefore, continual education of laboratory personnel and adherence to standard protocols for the diagnosis of parasitic infections in clinical parasitology laboratories around the world will be needed to maintain diagnostic accuracy and improve patient care (Arora et al., 2017)

Stool examination is an essential laboratory procedure for the diagnosis of intestinal parasitic infections and the evaluation of gastrointestinal health. Stool specimens need to be collected and analysed in order to find parasite eggs, cysts, trophozoites, larvae, blood, mucus, or abnormal organisms. The first part of the examination is macroscopic evaluation which includes assessing the stool consistency, colour, and visible abnormalities. The second part is microscopic evaluation, where details of the parasite structures are determined by preparing wet mount slides and staining. Stool examinations are very effective for identifying infections due to parasites, such as Entamoebahistolytica, Giardia lamblia, Ascarislumbricoides, and Taenia species. The recommendation to collect multiple stool specimens over several days is often made, since some parasites shed intermittently, so analysing only one specimen may produce inaccurate results. Using methods of concentration and permanent staining increases the sensitivity of the diagnostic methods and enhances the detection rate of parasites. Despite the increasing use of advanced molecular diagnostics, stool examination will continue to be an important component of routine clinical practice

because it is an easy and inexpensive way to test for parasites. The correct collection, handling, and storing of specimens is a critical factor for determining the accuracy of the test results. The laboratory staff must also follow strict quality control procedures to minimise possible errors and contamination of specimens. Thus, stool examination continues to be a key element in the early detection, treatment plan, and epidemiological evaluation of the worldwide occurrence of intestinal parasitic diseases (Leber et al., 2016)

Microscopy has been very important for diagnosing parasites because of its ability to correctly identify a parasite by seeing it directly. There are several different stains that can be used to make the parasite easier to see and more easily classified. The most commonly used stains to increase the visibility of parasites and increase the ability to identify species include giemsa stain, trichrome stain, and acid-fast stain. However, the best way to diagnose malaria is by examining a giemsa-stained blood smear; giemsa-stained blood smears provide the highest degree of accuracy when identifying the species of the Plasmodium that causes malaria and allow for the estimation of the number of parasites present. Examining samples of stool, urine, sputum and tissue microscopically is also a very useful method for identifying protozoa and helminths; using molecular techniques to evaluate the presence of parasites (such as PCR) is a more sensitive test than microscopy, however, many healthcare facilities still prefer to use microscopy for testing because it is less expensive and requires less support services. There are also limits to the quality of the test results in microscopy due to variability in the experience of the operator and sensitivity of the microscope, and because it may not be able to detect parasites when present in very low amounts, training and experience are critical to obtaining good results in microscopic evaluation. Today, whilst increasing number of laboratories around the world have combined the use of microscopy with various immunological and molecular techniques, ultimately, microscopy continues to be recognised as one of the very important diagnostic methods of parasitic disease that supports the best clinical decisions for the treatment of disease, disease follow-up and public health activities for parasitic disease worldwide (Garcia & Bruckner, 2018)

Modern diagnostic parasitology still relies on the continued use of microscopy and stool examination due to their ability to rapidly and efficiently identify parasitic infections.

Such techniques can be especially valuable in endemic areas, where parasitic disease prevalence is high and the availability of health care resources is limited. With microscopy, health care practitioners are able to visualize the morphology of the parasites, enabling them to correctly differentiate between the various species and phases of development. Stool examination is also essential to detecting intestinal parasites and evaluating the effectiveness of therapy. Laboratory improvements in diagnostic parasitology have been achieved through technology advancement, such as digital microscopy and fully automated imaging. Improved laboratory techniques have increased the diagnostic accuracy and decreased the possibility of observer-related error through the introduction of quality assurance programs and laboratory accreditation systems. Older diagnostic options that provide lower sensitivity than newer antigen detection assays and molecular diagnostic techniques still have some value in the routine laboratories. Often, these older diagnostics are utilized in conjunction with newer diagnostic techniques to achieve total and accurate evaluations of patients with suspected parasitic infections. Themerger of microscopy with laboratory innovations continues to enhance disease surveillance and optimize the delivery of health care (Procop et al., 2020)

PCR and ELISA improve parasite detection accuracy

PCR (Polymerase Chain Reaction) and ELISA (Enzyme-Linked Immunosorbent Assay) are sophisticated diagnostic methods that are now being applied extensively in clinical parasitology for accurate parasite detection. Compared to conventional methods of diagnosing parasitic infections, these two techniques have made it possible to identify infectious parasites with greater accuracy. PCR uses molecular techniques to amplify either the DNA or RNA of the infected organism, thereby making it possible to detect the organism even when the parasitic load is very low. ELISA is a serological test that utilizes blood/serum (or other body fluids) to identify either the presence of the parasite's antigens or to detect antibodies from the host; both techniques are very sensitive and specific methods of diagnosis and represent the new generation of testing equipment used in most modern laboratories. Some examples of parasitic diseases for which PCR and ELISA are commonly used for prompt and accurate identification include malaria, leishmaniasis, toxoplasmosis, and Giardia. The use of both techniques reduces

diagnostic errors, which are frequently made by using microscopy-based tests to make the diagnosis of parasitic diseases; PCR is important in identifying genetically similar species of parasites and co-infections of parasites, while ELISA is useful for large-scale screening and epidemiologic studies. As a result of using these two diagnostic methodologies, clinical decision-making, patient management, and disease control have all improved significantly. Collectively, these two diagnostic methods represent a significant advancement in diagnostic parasitology and have greatly improved the reliability of detecting parasites and subsequent health outcomes for patients (Gomes et al., 2016)

To date, PCR has changed the way parasitology is studied because this technique allows for highly and quickly sensitive identification of parasites through the amplification of their specific DNA material. With PCR, samples can be collected from patients who may already be infected with a parasite but who are not yet exhibiting any clinical symptoms, or from patients whose parasites are not readily visible using traditional microscopy techniques. This makes PCR very effective for detecting certain types of parasites, particularly blood and tissue parasites including Plasmodium spp., Trypanosoma spp., and Leishmania spp. ELISA provides complementary testing via the determination of parasite-specific antibodies/antigens contained in patient samples; therefore ELISA is appropriate for identifying both acute and chronic infections from parasite exposure. One of the primary advantages of these two techniques is a significant reduction in the number of false-negative results (which are common with traditional methods) that occur because of their high level of sensitivity. In addition, both PCR and ELISA provide the necessary tools to identify parasites at the species level, to explore genetic differences among parasites, and to establish whether acquired resistance exists to various anti-parasitic drugs. ELISA is frequently used in routine clinical laboratory settings and is preferred because of its relative simplicity and affordability while allowing for processing large numbers of patient samples in the same batch at the same time. When combined with traditional methods of diagnosis, both PCR and ELISA have improved diagnostic accuracy In developing countries with limited financial resources. Furthermore, for accurate diagnostic results to be obtained using either PCR or ELISA, proper laboratory infrastructure must exist, and staff performing

these assays must be trained on the operation and functioning of both techniques. Nonetheless, the use of PCR and ELISA will continue to be a key part of diagnostic parasitology moving forward into the future by greatly improving the detection of parasites causing infectious diseases and subsequently the care provided to individuals diagnosed with such diseases (Liu et al., 2017)

Parasitology utilizes a highly sensitive immunoassay method known as Enzyme-linked Immunosorbent Assay (ELISA) to isolate either parasite antigen or parasite-specific antibody produced by the host as an immune response to this infection. This technique has proven valuable in diagnosing the following infectious diseases: amoebic dysentery, Toxoplasma infection (toxoplasmosis), and Schistosoma infection (schistosomiasis). The ELISA test is based on the interaction between antigen and antibody; specifically, it is designed to produce a measurable color change that indicates infection via binding of antibody to antigen. The PCR technique detects the DNA or RNA of the parasite and is considered the "gold standard" for diagnosing parasitic diseases using molecular techniques. When combined together, both ELISA and PCR are highly effective means of confirming infection and increasing diagnostic accuracy of parasitic diseases. ELISA is particularly helpful in determining the occurrence of disease among large populations because it requires less skill to perform relative to PCR, making it clinically practical; PCR, however, provides superior sensitivity (ability to accurately detect parasites) versus ELISA and is used predominantly for confirming parasitic disease in small populations. Both techniques have enhanced epidemiological surveillance of communities by enabling researchers to determine the prevalence of paraesthesis among community members; they also assist in determining treatment-to-long-term monitoring of treatment response. While both techniques require technical training and laboratory resources to perform, the value of utilizing them for increasing diagnostic reliability outweighs the limitations of performing these tests. Consequently, the use and application of PCR and ELISA will continue to significantly improve contemporary parasitology diagnostic methods (Singh et al., 2018)

The use of PCR-based molecular diagnostics has significantly enhanced our ability to accurately diagnose parasitic diseases, particularly when normal diagnostic tests fail. PCR technology can amplify target DNA associated with parasites from clinical

specimens, enabling the detection of a single parasite organism. The above techniques are commonly used in the diagnosis of malaria and other protozoal infections such as cryptosporidiosis; ELISA provides immunological evidence through the detection of circulating antigens/antibodies, thereby enhancing confidence in the diagnosis and decreasing the number of misdiagnoses. The PCR method performs particularly well in identifying mixed infections and differentiating between two closely-related parasitic species that would appear to be identical by microscopic examination. Conversely, ELISA is frequently used in field studies and hospital laboratories because of its ability to test many samples simultaneously. Historically, when used alone or in combination, both PCR and ELISA have improved the early diagnosis of disease, allowing prompt treatment and decreased morbidity/mortality from the disease. The two methods also assist in the monitoring of drug resistance and in outbreak investigations. Although PCR and ELISA are generally more expensive than traditional laboratory techniques, they are becoming increasingly popular with clinical laboratories worldwide because of their high reliability and diagnostic value (Verweij et al., 2019)

The addition of PCR and ELISA to the field of clinical parasitology has led to an increase in the accuracy of parasite diagnosis and an increase in the efficiency of parasite diagnosis. PCR identifies parasites at the molecular level through the detection of specific genetic biomarkers, while ELISA identifies parasites indirectly by measuring the immune response or detecting parasite-specific antigens in individuals infected with that parasite. These two techniques are both used as diagnostic tools for confirming or excluding parasites in clinical settings, as well as serving as complementary diagnostic tests in research. The combination of PCR and ELISAs is very effective at identifying low parasitic levels, as well as identifying resistant strains of parasites. Rapidly screening individuals for parasitic infections and providing real-time epidemiological data are extremely important in resource-constrained settings, making the use of PCR and ELISA critical in these scenarios. By combining PCR and ELISA, PCR provides improved sensitivity and specificity over conventional diagnostic approaches for parasites. Additionally, when combined, PCR and ELISA have advanced our current understanding of the biology and epidemiology of parasites, as well as host-pathogen interactions. Thus, successful use of PCR and ELISA are dependent on adequate laboratory facilities,

quality assurance procedures, and competent, trained laboratory personnel to yield reliable results. Overall, PCR and ELISA are fundamental to modern parasitology diagnostic tests. The complementary relationship of PCR and ELISA has enhanced global disease surveillance systems, improving patient care through faster, more precise, and evidence-based parasitic disease diagnosis (Ndao et al., 2020)

Biomarkers assist in early diagnosis and disease monitoring

In clinical parasitology biomarkers allow for the early diagnosis and continuous monitoring of parasitic diseases. Biomarkers can be defined as measurable indicators of biological processes that represent the presence or absence of infection, disease progression and the immune response of the host to an infection by a parasite. In the case of parasitic infections, biomarkers can include nucleic acids, parasite-specific antigens and antibodies (immunoglobulins) and/or others molecules associated with a host inflammatory response to an infection. Early identification of these markers can allow clinicians to diagnose infections before the patient has developed serious clinical signs, which can greatly impact the outcome for the patient. This is particularly pertinent to malaria, leishmaniasis, and toxoplasmosis due to the need for early intervention for effective management of these diseases. Biomarkers can also assist in differentiating between active and previously infected patients, which is necessary for proper diagnosis and treatment planning. Conventional techniques can also lack sufficient sensitivity when dealing with low-parasite-load infections, thus limiting diagnostic capability for clinicians. Finally, when assessing patient response to treatment, biomarkers can aid in detecting reoccurrence or treatment failure. Advances in molecular biology and immunology have provided new opportunities to discover new biomarkers for diagnosing parasitic infections, and therefore improving the diagnosis and monitoring of these infections. In summary, biomarkers significantly enhance the ability to make timely and accurate diagnoses, manage and provide better outcomes for patients with parasitic infections and support decision making in the clinical setting while providing improved global health outcomes (McCarthy et al., 2017)

Biomarkers are now considered key components of clinical parasitology due to their ability to provide information on host-parasite interactions and immune response as well as to assist with improving the early diagnosis and tracking of the progression of

the infection. For example, HRP2 (a malaria-specific protein) is used as a biomarker to aid in the rapid diagnosis of malaria. Another example is that the detection of antigens (a type of biomarker) in leishmaniasis can allow for the diagnosis of an active leishmaniasis infection prior to the patient exhibiting signs or symptoms of the disease. Moreover, biomarkers can provide information about the progression of an infection, which will be beneficial to guide the selection of the most appropriate treatment options. In addition, the use of biomarkers can assist in the detection of infections that are otherwise difficult to diagnose using microscopy or other traditional diagnostic methods. Furthermore, biomarkers can enable epidemiological surveillance and assist researchers estimate the prevalence of a disease within specific populations. Biomarkers can also be used to evaluate the efficacy of antiparasitic treatments, by providing insight into changes in biomarker levels before, during and after treatment. Although some biomarker-based tests require a specialized apparatus, many point-of-care kits are available for utility in the field. As a result, the integration of biomarkers into the diagnostic process of parasitic infections has greatly enhanced the accuracy of diagnosis and, consequently, the quality of patient care in parasitic diseases, rendering biomarkers vital components of current clinical parasitology practice (Duffy et al., 2018)

The rise of biomarker usage in parasitology has allowed for better disease diagnosis, disease progression and early treatment monitoring. They can be derived from both the infectious agent and the immune response of the infected host. The most commonly used biomarkers include circulating parasite antigens, antibodies, cytokines and fragments of DNA from the parasites. They enable the health care professional to diagnose a parasitic infection earlier than was previously possible; often sometime prior to the parasite being diagnosed microscopically. This is particularly valuable in cases of chronic or latent infections, where clinical signs and symptoms may be very mild and/or nonspecific. In addition to helping to diagnose a parasitic infection, biomarkers also provide clinicians with valuable information regarding the severity and stage of disease. This information can be helpful in guiding the clinician to determine the appropriate type of treatment intervention. Furthermore, biomarkers can help clinicians assess how a patient is responding to treatment and also assist the physician to make decisions regarding the possibility of drug resistance developing. Continued improvements to

diagnostic methods by way of molecular technologies like PCR-based biomarker testing have enhanced the accuracy of parasite diagnostics. In addition, immunological assays such as ELISA support biomarker-based diagnostic testing of parasitic infections. While challenges like those related to cost and complexity of biomarker-based diagnostic methods exist, the adoption of biomarker-based diagnostics have rapidly; while playing an increasingly relevant role in modern parasitology (i.e., improving early diagnosis and management of disease) (Horning &Restrepo, 2019)

Biomarkers have proven to be a significant improvement to the accuracy of identifying parasitic diseases and have revolutionised how we detect and monitor patients at an early stage for treatment. Biomarkers allow us to identify an infection when symptoms are minimal or non-existent, enabling earlier medical intervention for the patient. A reliable way to confirm a parasitic infection like malaria, schistosomiasis or toxoplasmosis is to test for specific parasite antigens or the host's immune response. Methods typically used to detect these markers include immunological assays or molecular assays, both of which have significantly greater sensitivity than traditional diagnostic methods. Biomarkers also assist in differentiating between acute and chronic infections and will help to determine an appropriate course of treatment. Additionally, biomarkers are essential in monitoring the effectiveness of treatment by measuring changes over time in the level of the biomarker being monitored. This information is useful for clinicians to determine if the patient is responding to treatment or if a modification in treatment is warranted. Lastly, biomarkers are important for public health surveillance as they can provide an estimate of the incidence and geographical distribution of an infection in a population. There are some limitations to their use, such as variability of biomarker expression and the requirement for specialised equipment; however, new research continues to improve the dependability of biomarkers as well as accessibility to the clinical setting (Weiss et al., 2020)

The introduction of biomarkers into the arena of diagnostic parasitology has revolutionized this field by offering reliable, highly specific, sensitive, and timely tools for the early identification of an infection, and follow-up assessment of an infected individual’s disease status. Biomarkers consist of parasite-derived molecules and host derived response indicators that can be measured from various biological matrices such

as blood, stool or tissue. Biomarkers are particularly valuable for the identification of subclinical infections for which traditional diagnostic techniques may not be effective. Antigen based biomarkers, for example, are routinely used in rapid diagnostic tests for malaria that facilitate the initiation of prompt and appropriate treatment. Molecular based biomarker tests that utilize the parasite's DNA provide a more accurate species identification and detection of drug resistant strains. Biomarkers also provide an accurate assessment of treatment success by indicating whether or not the parasite has been eliminated from its host. The successful application of biomarkers in routine clinical practice has improved patient management by permitting timely and targeted treatment decisions. In addition, the investigation of biomarkers has enhanced our knowledge of parasite biology and the host immune response to parasitic infections. Despite limitations related to cost and laboratory capacity, biomarkers will continue to improve the accuracy of diagnosis, and support efforts to control disease in our society. Biomarkers represent an invaluable resource for contemporary parasitology, facilitating the accurate diagnosis of disease and supporting the development of long-term disease monitoring strategies in all regions of the world (Reiner et al., 2021)

Evidence-based therapies improve patient treatment outcomes

The use of EBM (Evidence-Based Medicine) in clinical parasitology significantly enhances patient outcome results from parasitic infections by using valid scientific data, clinical trial results, and up-to-date clinical guidelines when determining how to treat patients. Correct drug choice and dosage are critical components of achieving total parasite clearance (the total number of parasites eliminated from the host) and prevention of complications from parasitic diseases. Clinicians will utilize EBM principles when selecting the most appropriate medications to treat their patients. Based upon the type of parasite the patient is infected with, the severity of the infection, and the overall health status of the patient, clinicians may utilize one or more of the following medications, to name just a few examples; albendazole, ivermectin, metronidazole, artemisinin-combination therapies. By utilizing EBM principles, healthcare professionals may reduce treatment failure rates and improve patient recovery rates by following standardized treatment protocols. EBM also decreases the likelihood of prescribing errors or experiencing adverse drug events. Additionally, EBM supports the rational use

of medications, which is critically important in preventing the development of drug resistance in parasites. Clinical guidelines that are developed by health organizations will allow for the consistent application of treatment guidelines across multiple health care settings. In conclusion, the use of EBM helps improve patient outcome results by providing safe and effective treatment options that have been proven through scientific study and validation and will ultimately lead to a better understanding of how to control disease and strengthen the global healthcare system (White et al., 2019)

Evidence-based treatments in clinical parasitology are essential for successful outcomes for our patients as we combine clinical and scientific expertise. Although the clinical presentation of parasitic infections can vary in severity, each patient will require a uniquely tailored approach to the treatment of their infection; therefore, accurate diagnosis and laboratory results are critical to individualized treatment. Evidence-based treatment guidelines will allow healthcare professionals to administer the most effective drug for the specific type of parasitic infection to reduce the risk of treatment-related complications. For example, the use of combination therapies in the treatment of malaria is designed to increase the effectiveness of the treatment and to decrease the occurrence of parasite resistance. Evidence-based therapies also ensure that the duration of treatment and the dosing are appropriate to effectively eliminate the entire parasitic infection. At the same time, these therapies will decrease the use of unnecessary medications, which ultimately minimizes the likelihood of developing side effects and maximizes patient safety. We rely on current clinical guidelines and systematic reviews to provide healthcare professionals with evidence to make the best treatment decisions for their patients. This approach also would enable continuous improvement to the quality of healthcare through the implementation of new findings from research studies into clinical practice. Evidence-based therapies result in increased recovery rates, reduction in mortality, and improvement of healthcare for patients diagnosed with parasitic disease (Murray et al., 2020)

The use of evidence-based therapy for parasitic diseases has led to significant improvements in patients' outcomes because of the emphasis on utilizing proven, effective treatment protocols created through substantial clinical study and based on the latest developments in parasitology. The use of evidence-based treatment for

parasitic diseases ensures that the correct medication will be utilized for the appropriate parasite, which translates into increased success rates when treating parasitic infections. For example, praziquantel has proven to be very effective in treating schistosomiasis, while ivermectin has proven to be the best method for treating onchocerciasis. The use of evidence-based guidelines can aid healthcare professionals' ability to treat other drug resistant infections with the use of alternative therapies or medications. The increased simplicity and decrease in side effects of evidence-based therapies will also encourage patient adherence to their respective treatment regimens. Evidence-based care includes both monitoring and follow-up to give clinicians the ability to gauge the effectiveness of specific methods and adjust their approach as appropriate. Use of evidence based therapies not only improve the individual outcomes of patients affected by parasitic infections, but have also been designed to improve public health by reducing the transmission and recurrence of disease. For this reason, effective management of parasitic disease includes the use of evidence-based therapies (Keiser &Utzinger, 2018)

Using evidence-based therapies to treat parasitic infections leads to better patient care because treatment decisions come from sound clinical data instead of just "the way it's always been done." By using evidence-based practice, providers can create more precise, effective treatment plans – which translates into better patient outcomes. Evidence-based medicine (EBM) is comprised of data from clinical trials, meta-analyses, and applicable global health recommendations, all helping to direct how a provider will choose a therapy for their patient. Prior to initiating treatment for a parasitic infection, it is important that the patient is properly diagnosed so that the right medication can be given. The use of evidence-based therapies also involves the use of combination drug therapies. This approach has shown to be very beneficial for use against complex parasitic infections such as malaria or leishmaniasis, by minimizing resistance to these drugs while maximizing the rate at which parasites are eliminated. Using an evidence-based approach results in the reduced number of medications prescribed, thus decreasing overall health care expenditures and decreasing the number of adverse drug reactions. Ongoing medical education and revised clinical practice guidelines allows clinicians to remain aware of the latest improvements in treating patients. In turn,

patients will receive safer, more effective, and standardized treatment methods leading to a quicker and better recovery with improved long-term health (Prasad et al., 2021)

Evidence-Based Therapies Have Changed The Way Parasitic Diseases Are Treated. They Do So By Using Valid Scientific Evidence As The Basis For Clinical Decision-Making. Evidence-Based Therapies Improve Treatment Outcomes And Ensure Patients Receive The Most Appropriate And Effective Treatments. Treatment Of Parasitic Diseases Is Successful Only If The Diagnosis Is Correct, The Right Drug Is Given, And The Correct Clinical Guidelines Are Followed. Evidence-Based Medicine Helps To Standardise Treatment And Reduce Variability In Treatment Across Healthcare Systems By Providing A Framework For Evidence-Based Treatment. Evidence-Based Medicine Plays A Crucial Role In Combating Drug Resistance By Promoting Rational Drug Use And Combination Therapy Where Appropirate. Evidence-Based Medicine Facilitates Better Patient Monitoring By Allowing Healthcare Professionals To Monitor Patients Progress, Determine How Well The Treatment Is Working, And Make The Necessary Adjustments In A Timely Manner. Evidence-Based Medicine Incorporates Evidence From Laboratories, Clinicians, And The Current Literature And Uses Them To Assist Clinicians With Making Decisions In Their Daily Practice. Evidence-Based Medicine Increases Patient Safety, Reduces Complications, And Improves Recovery Rates Of Patients. Ultimately, Evidence-Based Therapies Are An Essential Element For Providing Quality Health Care In Parasitic Disease Therapy, Providing Patients With Better Healthcare Outcomes Throughout The World (Graham et al., 2022)

Antiparasitic drugs are used to control infections effectively

In the field of clinical parasitology, antiparasitic medications are necessary to effectively control and eliminate parasitic infections in humans. These drugs are designed to target various stages in the life cycle of parasites and either kill the parasite or prevent its growth and reproduction. Some common antiparasitic medications include metronidazole (effective against protozoal infections), albendazole (effective against intestinal helminths), ivermectin (effective against ectoparasites and nematodes), and artemisinin-based combination therapies (ACTs) (effective against malaria). The specific antiparasitic medication selected will depend on the type of parasite being treated, the severity of the infection, and the overall health of the patient. By increasing cure rates

and decreasing complications from parasitic infections, these medications have made significant contributions toward decreasing the global burden of parasitic diseases. The most effective form of antiparasitic therapy employs accurate diagnostic techniques to ensure that the appropriate medication is given for the specific type of parasite. Achieving complete parasite elimination and preventing relapse also requires appropriate dosing and length of treatment. Additionally, these antiparasitic medications play a significant role in public health initiatives designed to reduce the incidence and prevalence of endemic parasitic diseases. Altogether, antiparasitic medications are a fundamental component of contemporary parasitology and serve as highly effective methods for controlling infections and helping patients recover from infectious diseases globally (Stauffer et al., 2018)

Antiparasitic drugs are an important part of healthcare systems since they are used to control the millions of people worldwide who have different parasitic infections. Antiparasitics work by interfering with the biological processes that occur in the parasites; for example, albendazole will disturb the formation of microtubules in helminths, while metronidazole will affect on the DNA of protozoans. Antimalarial artemisinin-based compounds work well against malaria by rapidly reducing the parasite burden in the bloodstream. Early diagnosis and appropriate treatment selection are key to the success of antiparasitic drugs. Most frequently, combination therapies are used to enhance the efficacy of the drugs and to limit the development of resistance by parasites to the drug(s). Antiparasitics are also utilized in mass drug administration (MDA) programs to help prevent infections in endemic areas. The effective use of antiparasitic drugs is also important since improper use can result in reduced efficacy and increased resistance; therefore, there must be appropriate prescribing. Healthcare providers are expected to use evidence-based practice guidelines when prescribing these drugs to provide patients with safe and effective treatment. In summary, antiparasitic drugs are essential components of global strategies to control parasitic diseases and to improve public health (Hotez et al., 2019)

Antiparasitic medications form part of the basic management and treatment of parasitic diseases globally because they act specifically on particular parasites and interfere with their life cycles, thus allowing them to be removed from the body of the

host. Antiparasitic medications are classified by their mode of action against various types of organisms, such as antiprotozoals, anthelmintics, and ectoparasiticides. For example, praziquantel is an effective medication for treating schistosomiasis, while ivermectin is widely used in treating onchocerciasis and strongyloidiasis. Antiparasitic drugs have made a substantial reduction in the morbidity and mortality associated with parasitic illness. However, the growing incidence of drug-resistant parasites is an increasing problem in clinical parasitology. The search for new drugs, including the potential for combination treatments, is currently being pursued as possible ways of overcoming this problem. Proper diagnosis and adherence to treatment protocols are essential in ensuring maximized drug efficacy. Antiparasitic drugs are used in primary prevention strategies through mass treatment programs in endemic areas. Therefore, the role of antiparasitic medication in controlling parasites is critical in clinical and public health settings (Keiser et al., 2020)

By eliminating or controlling parasite populations within the human host, antiparasitic medicines are a vital part of reducing the burden of parasitic infections and therefore play a very important role in the treatment of these types of infections. Antiparisitic agents can work via several methods including: inhibition of parasite enzyme systems, disruption of parasite cellular structures and intervention with metabolic pathways. For example, chloroquine blocks heme detoxification in malaria parasites, and albendazole inhibits glucose uptake in helminthes. The effective use of antiparasitic therapy is reliant on timely identification of the infection, appropriate drug selection and patient adherence to the regime. Many times, combination therapy is recommended to enhance efficacy and reduce the development of resistance. Antiparasitic agents are also used in prophylactic chemotherapy programs to prevent infection within high-risk groups. Although there are significant barriers including drug resistance, side effects and limited availability in the poorest parts of the world which can hinder treatment success, continued research and development of new antiparasitic agents are necessary to address these issues. To summarise, these medicines are critical to effectively managing diseases caused by parasites and improving global health (Fairlamb et al., 2017)

The utilization of antiparasitic medications is a key element in controlling and managing the parasitic disease burden across the world. Most antiparasitic medications are used to treat individual patients and/or in mass public health interventions. Their effectiveness stems from their ability to kill parasites at various life cycle stages. Antiparasitic medications (e.g., ivermectin, albendazole, praziquantel, and artemisinin-derived combinations) have provided significant reductions in the burden of disease in many endemic areas. Mass drug administration programmes have been especially effective against neglected tropical diseases. However, the long-term success of antiparasitic medications is contingent upon their proper use, adherence to guidelines, and prevention of drug resistance. It is essential to monitor treatment results and provide periodic surveillance to ensure the future effectiveness of antiparasitic medications. Using preventive measures (i.e., improved sanitation, vector control, health education) concurrently with drug treatments can strengthen efforts to control disease transmission. Currently, though challenges still exist, antiparasitic drugs are still one of the most effective approaches to decrease the global burden of parasitic diseases and improve population health status (Savioli et al., 2021)

Drug resistance is a major challenge in parasitology

Drug resistance poses a significant challenge in parasitology, impacting the effectiveness of antiparasitic drugs and complicating their use for treatment due to the parasites ability to survive exposure to the drug despite prior susceptibility. This is especially relevant for parasite-associated diseases like malaria, leishmaniasis, and intestinal helminthiasis. For example, multiple areas of the world have recognized that both chloroquine and artemisinin-based therapies used to treat malaria are losing efficacy due to drug resistance, which has resulted in higher morbidity and mortality rates than would be expected. Drug resistance occurs when a parasite develops a genetic mutation that allows it to survive when exposed to an antiparasitic drug, and it can continue to reproduce regardless of the effectiveness of the drug. Drug resistance may develop for a variety of reasons, including genetic mutations in the parasite, inappropriate use of drugs, not completing a treatment course, or overuse of antiparasitic drugs leading to resistant strains. These factors create opportunities for resistant strains of parasites to continue reproducing and spreading so that standard

treatment protocols become less effective and require higher doses of medication; combinations of medications; or medications that are not normally used to treat the particular parasite that is being treated. These developments increase the cost of treating these diseases and complicate the management of these diseases. Finally, the ongoing development of global health initiatives to control parasitic infections are hindered by the continued development of drug resistance in endemic areas. To help alleviate and reverse the impact of drug resistance on parasitic diseases globally, continuous monitoring, research, and development of new medications will be necessary to continue effective control of parasitic diseases worldwide (Haldar et al., 2018)

Over the years, there has been a growing concern with regard to global health issues. Among these, drug resistance in parasites & drug resistance in patients who have been infected with parasites is becoming an increasingly prevalent problem, especially amongst those living in malarious areas of the world where multiple antimalarial-resistant strains of parasites exist. Parasites develop resistance based on genetic changes that allow them to survive & reproduce, even after treatment with anti-parasitic drugs. The result is treatment failure, protracted periods of illness, & a high number of patients infected with a resistant strain. Drug misuse, patient non-adherence, self-medication, & inadequate diagnostic testing prior to treatment all contribute to the increased incidence of drug resistance. In addition, inappropriate dosing & incomplete therapies are contributing to the accelerated development of resistance. To help counter this trend, combination therapies such as artemisinin-based combination therapy (ACT) are being utilized to improve the overall efficacy of treatment & delay the development of resistance. In conjunction with combination therapy, ongoing surveillance programs are essential for monitoring patterns of drug resistance to help formulate treatment guidelines & policies. Developing drug resistance not only impacts the patient treated for a parasitic infection but also has widespread implications for public health & the overall cost of healthcare as more drug-resistant parasites develop & the available treatment regimens for these parasites become more limited. Therefore, an ongoing commitment to the rational use of drugs, an accurate diagnosis, & ongoing research will

be crucial in addressing the management & prevention of drug resistance in parasitic diseases (Ashley et al., 2019)

Drug-resistant parasites present large obstacles to widespread efforts to control and eliminate parasite diseases around the globe. Resistance can arise from parasites adapting to resist exposure to antiparasitic medications through the development of genetic mutations or being subjected to selective pressures from wide-spread use of medications for extended periods of time. In the case of malaria, resistance to chloroquine and sulfadizine-pyrimethamine has resulted in fundamental changes in treatment protocols. There is also increasing reporting of resistance in both helminths and protozoa, making it more difficult to treat these infections, leading to longer periods of illness, greater rates of illness transmission, and increased mortality rates. One of the leading causes for developing resistance is the inappropriate use of medications, including incomplete treatment courses and purchases of medications over the counter and using for indications other than what they were originally developed. Healthcare systems have initiated the use of combination therapies and created structured treatment protocols to address this problem. Monitoring the effectiveness of medications through laboratory-based testing will also aid in detecting the presence of resistance early on. Continued research into the development of new antiparasitic compounds and alternative approaches to treatment is being conducted. Coordinated efforts must be developed by clinicians, researchers, and public health agencies to address drug resistance to ensure the long-term effectiveness of disease control strategies (Wongsrichanalai et al., 2020)

Parasitic infections can be effectively treated with anti-parasitics; however, drug resistance greatly reduces the effectiveness of all forms of treatment for parasitic infections and is an impediment to controlling disease. Drug resistance is developed, when, through genetic mutation, a parasite becomes less sensitive to an anti-parasitic compound. Multi-drug resistance has been demonstrated with malaria parasites, resulting in ineffective treatments. Likewise, the increased frequency of mass drug administration of anti-parasitic drugs has resulted in increased rates of drug resistance in helminthes. Prescription errors (incorrect dosing), substandard drug supplies, and lack of therapy adherence by patients are all contributory factors to the emergence of drug

resistance. As a result, in order to provide safe and effective treatment to patients with parasitic infections, healthcare professionals may have to utilize more expensive or more dangerous alternative agents. Use of combination therapy is one of the most effective strategies to delay the emergence of drug resistance and improve treatment outcomes. Routine monitoring of the effectiveness of antiparasitic drugs, as well as drug resistance patterns, are necessary to help in developing new treatment guidelines. The public health education of healthcare professionals and strict prescription regulation are also essential to prevent the misuse of anti-parasitic drugs. Drug resistance continues to be a global problem requiring the ongoing attention of healthcare providers and researchers (Utzinger et al., 2018)

The growing problem of drug resistance in parasitology threatens global efforts to control infectious diseases caused by parasites. Resistance reduces the effectiveness of standard treatments and leads to increased disease burden, especially in low-resource settings. Parasites such as Plasmodium, Leishmania, and various helminths have shown increasing resistance to commonly used drugs. This resistance develops through natural selection, where resistant parasites survive drug exposure and multiply. Contributing factors include overuse of antiparasitic drugs, lack of proper diagnostic testing, and incomplete treatment regimens. Drug resistance results in higher treatment failure rates, longer illness duration, and increased healthcare costs. To manage this issue, international health organizations recommend rational drug use, combination therapies, and continuous surveillance of resistance patterns. Research into new drugs and alternative treatment strategies is also essential for long-term control. Public awareness and healthcare education are important in preventing misuse of medications (Kyu et al., 2021)

Conclusion

Clinical and diagnostic parasitology is kind of a key branch in medical science, it sort of sits in the middle of how we spot, manage, and even try to control parasitic infections that affect people everywhere. If diagnosis is done carefully and quickly , it supports everything else. With older more traditional routes like microscopy and stool examination , plus newer approaches such as PCR, ELISA, and biomarker based testing , clinicians can catch infections with more precision, and often earlier than we used to.

That early detection matters a lot because it lets healthcare teams step in sooner , and that can reduce the chance of complications, while also improving patient outcomes. At the same time evidence driven therapeutic strategies help make sure the right antiparasitic drugs are chosen and used in the proper way. When that happens, treatment tends to work better, and the overall disease burden goes down. Still , there are persistent obstacles. Drug resistance keeps showing up, and it can weaken many international control efforts for parasitic diseases , so the world still needs continuous work ongoing surveillance , and the development of new medications. On top of that, linking modern lab technologies with evidence based medicine has basically strengthened healthcare systems, and it improves how parasitic infections are tracked and handled. Biomarkers together with molecular tools contribute too , they make monitoring and patient follow up more reliable, not just guess work. So overall, clinical and diagnostic parasitology stays important for global public health, especially in regions where these infections are highly endemic and common. To keep progress moving, continued innovation, interdisciplinary cooperation, and better healthcare infrastructure

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