CANCER PEDIA

CLINICAL SERVICES

LABORATORY MEDICINE AND PATHOLOGY

Contributors: Sylvia Asa, Tom Clancy, Amanda Chudak, Brad Davis, Mary Fountas, Michele Henry, Suzanne Kamel-Reid, John Racher, Auro Viswabandya, Mary Gospodarowicz

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CHAPTER
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LABORATORY MEDICINE AND PATHOLOGY

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A. INTRODUCTION

Laboratory medicine and pathology (LMP) is a fundamental for cancer care. Everyone with suspected or confirmed cancer will have some type of laboratory test. LMP services examine human tissue, cells, fluids or their derivatives to meet a number of goals. They are critical for securing a definitive cancer diagnosis and provide important information to define the most appropriate course of treatment.

This chapter presents the essential elements required to establish and implement a laboratory medicine and pathology service as part of a comprehensive system of cancer care, including the goals and scope of the service, the resources required, management and quality performance considerations, and a look forward to future trends and innovations.

B. OVERVIEW

1. GOALS

The goals of the LMP service are to support the diagnosis, treatment and monitoring of patients.

Informing the Diagnosis and Treatment of Cancer

LMP performs a wide array of laboratory tests on specimens collected from individuals, including tissue samples obtained in a clinic setting or during a diagnostic surgical procedure and blood or bodily fluids. These tests detect the presence of abnormal cells or tumour markers, which include specific proteins or genes that may signal the presence of cancer. They also determine genetic, epigenetic and proteomic cancer characteristics.

In addition to performing tests, LMP ensures that all laboratory results and pathology reports are provided to requesting healthcare providers. Generally, these results and reports are interpretive and outline the anatomic disease extent. Laboratory tests provide the grade of cancer based on how different the collected cells look from normal cells, reflecting how quickly they are growing and dividing and how likely they are to spread. Laboratory medicine specialists/pathologists use standard cancer staging and grading systems to classify cancers (e.g., see Sobin et al. 2009).[1] This information is critical for determining a prognosis and making treatment decisions.

Monitoring the Impact and Effectiveness of Treatment and the Recurrence of Cancer

LMP also performs laboratory tests after a diagnosis, and during and after treatment. This testing assesses the effectiveness of treatment, identifies any complications resulting from treatment and determines whether the cancer has progressed or recurred after treatment.

2. SCOPE

A comprehensive LMP service in a cancer centre should include the following major disciplines.

Biochemistry, which analyzes blood gases, enzymes, immunoglobulins, hormones, metabolites and tumour markers.

Hematology, which analyzes blood to identify and diagnose diseases and disorders, and generally includes:

- Routine hematology
- Coagulation
- Flow cytometry, to examine microscopic particles, such as cells or DNA, and determine cell types

Microbiology, which provides diagnostic information about infections caused by bacteria, fungi, parasites and viruses, and monitors patient responses to the treatment of infections.

Transfusion medicine, which collects, processes, manages and distributes blood and blood products.

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Anatomic pathology, which includes:

- Surgical pathology, to analyze tissues obtained by a surgical procedure.
- Histopathology, to examine stained tissue and cells using a light or electron microscope.
- Cytopathology, to analyze abnormal cells in body fluids, smears and tissue samples.
- Immunohistochemistry, to treat tissues or cells with antibodies and detect abnormalities.
- Electron microscopy, to analyze tissue using advanced electron microscopes.

Genetics, which includes:

- Cytogenetics, to analyze chromosomes and detect genetic abnormalities
- Molecular genetics, to analyze genes and detect abnormalities.

Cellular therapies, which require:

- Histocompatibility testing, including human leukocyte antigen (HLA) typing. HLA typing analyzes inherited HLA proteins or markers to determine an individual's HLA type and to assess the extent of a tissue match between individuals (i.e., for the purposes of tissue donation).
- CD34+ hematopoietic stem/progenitor cell enumeration. A minimum CD34 cell dose is required for adequate engraftment (i.e., blood count recovery) post-stem cell transplantation.

Within each of the disciplines, numerous routine and highly-specialized laboratory tests can be used to screen for cancer, inform diagnosis and treatment, and monitor the impact of treatments and cancer recurrence. More sophisticated testing regimens are constantly being developed within each discipline and across disciplines.

The scope of the overall clinical services provided by a cancer centre should dictate the scope of the LMP service. Appropriate resources are required to support LMP. More complex and advanced LMP tests that require specialized equipment, expertise, and high capital and operating costs may best be provided in partnership with one or more other centres; that is, one cancer centre may be the referral site for less developed centres that do not offer sophisticated testing on-site. When services are shared between institutions, LMP can be augmented by the digital transfer of images.

3. PATHWAY

Figure 1 presents the LMP pathway, which is categorized into pre-analytic, analytic and post-analytic phases.

- The ***pre-analytic phase*** includes ordering the test, collecting the specimen, transporting the specimen to the laboratory and receiving the specimen at the laboratory.
- The ***analytic phase*** includes processing the specimen for analysis, analyzing the specimen and interpreting the test results.
- The ***post-analytic phase*** includes recording test results data, reporting test results to the requesting clinician to guide their diagnostic and therapeutic decisions, and storing specimens and records.

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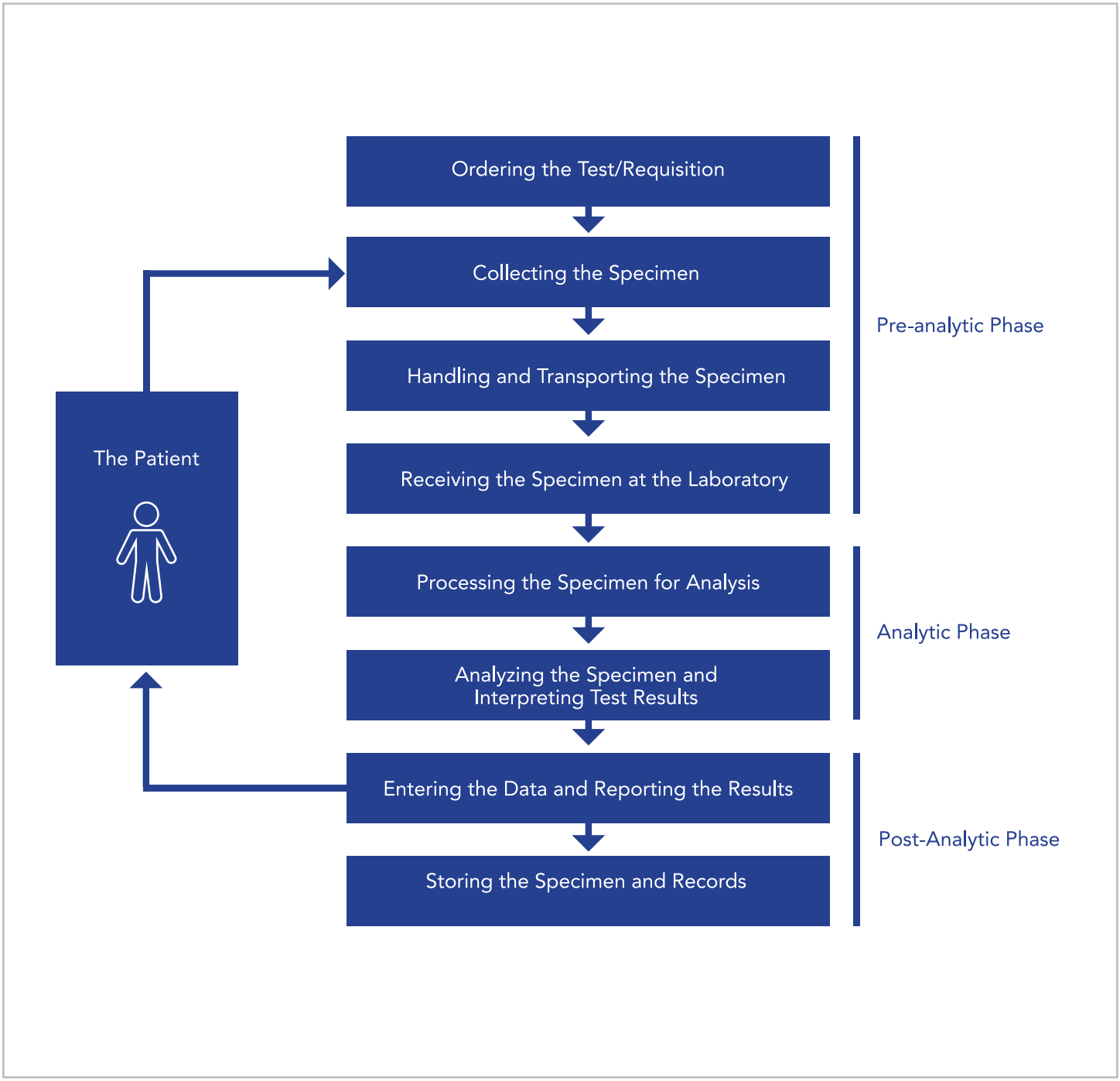
Figure 1: Laboratory Medicine and Pathology Pathway



The LMP pathway begins when a surgeon or other clinician assesses the patient and orders one or more laboratory tests. The selection of tests must be guided by evidence-based standards and guidelines. Tests should ideally be requisitioned through an electronic order entry system to ensure that consistent and appropriate information is recorded for use by the healthcare team and LMP staff. The requesting clinician or a member of the healthcare team must provide the patient with information about the ordered tests, including the reason for the tests, what to expect and any potential side-effects that may occur. Patients must also be informed of any preparatory measures that are required prior to testing.

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Various professionals may collect patient specimens, depending on the type of specimen and the jurisdictional scope of practice of each profession. In a cancer centre or other hospital, specimens may be collected by surgeons in the operating room, by surgeons or other clinicians in a biopsy clinic, by clinicians on inpatient units and in outpatient clinics, or by technical experts (e.g., blood). Technical experts may also provide assistance in ensuring appropriate sample collection, such as with bone marrow or fine needle aspirates. In the community, community-based care providers may take tissue samples, blood or body fluid samples in their offices. In all cases, specimens must be collected according to evidence-based standards and guidelines, and using appropriate methods.

Information and education must be provided to requesting clinicians about specimen collection and integrity. Typically, specimens are transported directly from the operating room, biopsy clinic, inpatient unit or outpatient clinic to the laboratory for analysis. Special consideration must be given to specimen handling procedures, to ensure both the integrity of samples (e.g., so that biomarkers do not degrade) and the safety of staff transporting samples (e.g., infection prevention). For physical specimens, best practice standards address the selection of appropriate collection containers (i.e., with appropriate additives and anticoagulants), the order of draws, acceptable handling and transport times, appropriate transport and storage temperatures, and shipping requirements.[2] For digitized specimens (i.e. high-resolution electronic images), best practice standards address issues associated with taking and sending images, including quality and privacy. Point-of-care testing (POCT) – where patients are tested using portable instruments and test kits (e.g., blood and urine strips) and provided with immediate results in the operating room, at the bedside or in an outpatient clinic – eliminates specimen transport and can accelerate the flow of patient care and diagnosis; regardless, appropriate measures must be taken to ensure that all testing meets rigorous standards for collection and handling.

The laboratory receives physical specimens for testing through a central receiving area. When a specimen arrives in the laboratory, it is assessed to determine if it is acceptable for the requested test. This includes ensuring that the integrity of the specimen has not been breached, ensuring that there is sufficient volume to support testing and confirming adequate patient identification. The specimen is then assessed for pre-analytical processing, handled accordingly and redirected to the appropriate laboratory station testing area.

Laboratory experts conduct tests on specimens to derive results. Findings are correlated with the patient's clinical information to make a diagnosis. Additional tests may be performed to make a final diagnosis or to determine the specific origin of a tumour, the grade or hormone status of a tumour, or the type of bacteria present. Molecular or cytogenetic studies may also be performed to determine relevant genetic information.

When testing is complete and laboratory medicine specialists/pathologists have reviewed, interpreted and verified the test results, the test results, the interpretation of the test results and the pathological diagnosis are recorded in the patient's health record. Test results are typically communicated by the laboratory to the requesting clinician in the hospital or community. The requesting clinician is responsible for reviewing and communicating the results to the patient. A member of the healthcare team must be available to discuss test results with patients, providing explanations, outlining follow-up measures and answering questions, as required. In some cases, patients are able to access their test results directly, either by calling the laboratory or by accessing a secure and password-protected electronic patient portal; in all cases, the requesting clinician remains accountable for verifying the test results and determining the next steps in a patient's care.

Specimens are part of the patient's health record.[3] When testing is complete, all specimens and records should be stored for an appropriate amount of time. Diagnostic tissue that undergoes gross examination, but is not processed further for analysis is regarded as excess diagnostic tissue. This tissue is usually retained for a shorter period of time before being discarded as medical or biological waste.[3] Diagnostic tissue that has been processed and analyzed is usually archived for longer periods of time, in accordance with statutory and laboratory licensing and accreditation requirements, before being discarded. Storage retention times and requirements vary by jurisdiction, type of laboratory medicine, population and disease.[4] Storage time also usually varies depending on whether the tissue is for diagnostic or research purposes. Research tissue may be stored indefinitely in a research biobank, with patient consent.

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C. RESOURCES

The resources required for a laboratory medicine and pathology service include physical facilities and equipment, human resources and an information management infrastructure. The core resources required by the LMP service are standard; however, various factors may impact the level and configuration of resources across centres. For example, more resources may be required to support highly-specialized laboratory and pathology equipment and tests. Similarly, a cancer centre that is part of a larger healthcare facility may be required to configure its LMP service to support clinical programs beyond cancer.

4. FACILITIES AND EQUIPMENT

The cancer centre must have an adequate and appropriately designed facility infrastructure to support all LMP processes. These include ordering tests, collecting and identifying specimens, transporting, preparing and analyzing the specimens, reporting and interpreting results, acting on the results, and storing specimens and records.[5] LMP processes span various areas of the hospital, from the operating room to inpatient units and outpatient clinics to the laboratory.

Important considerations for LMP facilities include:

- Links between each step of the LMP pathway, to support the timely, effective, efficient and secure flow of specimens, the patient's right to the privacy of their specimens and information, and a safe working environment for staff.
- The location of LMP service areas, including necessary adjacencies (e.g., which areas must be directly connected or located in close proximity to one another).
- Specimen integrity throughout the LMP pathway, including procuring, handling, transporting, analyzing and storing specimens.

A well-designed laboratory infrastructure requires the participation and input of laboratory leadership and staff. LMP experts should also review processes that occur outside the laboratory, but that impact laboratory operations and specimen integrity. In particular, planning for POCT must involve LMP staff that are responsible for the quality assurance of remote equipment and the processes used for testing.

All decisions about facility infrastructure must meet the building and biosafety standards and requirements set by local, regional, provincial/state and national regulatory bodies. International guidelines and standards may also exist and should be considered.

Pre-Analytic Phase

Ordering the Test / Requisition

Patient assessment and the process of requesting tests may occur in existing areas of the cancer centre – such as procedure rooms, operating rooms, inpatient units or outpatient clinics – or in spaces dedicated specifically for LMP activities. It is ideal for orders to be submitted electronically through a computerized order entry system, but robust paper-based systems are used effectively in many institutions.

Collecting the Specimen

Collection of specimens should occur away from the main laboratory. Most specimens are collected in operating rooms, in biopsy clinics, on inpatient units or in outpatient clinics using space already designated for patient care. The cancer centre must ensure that its facilities and equipment allow for specimens to be collected and handled using appropriate and safe methods, as per guidelines and standards. A dedicated frozen section or other specialized facilities may be required in some areas.

Handling and Transporting the Specimen

Typically, specimens are transported directly from the operating room, biopsy clinic, inpatient unit or outpatient clinic to the laboratory. Dedicated surgical suite staff may transport samples to the laboratory. Centres may also have an automated or pneumatic tube system that carries physical specimens from

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various patient care areas to the laboratory, a high-resolution electronic imaging system that allows for the communication of digital information between the operating room and the pathologist, as well as appropriate space for the review and interpretation of these images. In some cases, external facilities may send physical specimens or high-resolution electronic images to the cancer centre for LMP analysis.

Receiving the Specimen at the Laboratory

The central receiving area should be adjacent to the entrance of the laboratory to receive specimens, supplies and staff as they flow into the laboratory. It should also be adjacent to, but physically separated from, the area of the laboratory where specimen testing occurs, and include appropriate areas for:

- Specimen receipt, sorting, and dispatch
- Specimens that need immediate analysis (i.e., stat receiving area)
- Specimens that are time sensitive and/or require pre-analytical processing, to ensure sample integrity is not compromised during the time it takes the sample to arrive at the analytical phase (e.g. centrifugation and aliquoting)
- Specimens that need to be redirected to an external facility for testing (e.g., highly-specialized testing)
- Holding specimens to be tested at a future date
- Holding specimens that are received after hours

The central receiving area should ideally be linked to an electronic laboratory information system (LIS) that documents and provides a unique identifier (i.e., bar code label) for each specimen. The LIS also documents laboratory results and is linked to the patient's health record.

Analytic Phase

The analytic phase occurs in the laboratory, with the exception of POCT. Numerous standards and guidelines exist for hospital laboratory physical infrastructure at the international, national and subnational levels. Depending on the jurisdiction, laboratories and specific laboratory departments may need to meet mandatory standards.

At the international level, the International Organization for Standardization (ISO) develops voluntary global standards in a wide range of areas, including laboratory medicine.[6] Other examples of organizations that set standards and guidelines for laboratory physical facilities include the following:

- The Canadian Biosafety Standards and Guidelines include standard requirements for physical containment (i.e., engineering controls and facility design) and operational practices (i.e., administrative controls and procedures) for facilities where infectious materials or toxins are handled or stored.[7]
- The Canadian Standards Association offers laboratory and healthcare standards, which include requirements and guidance for infrastructure planning, design and construction.[8]
- The Institute for Quality Management in Healthcare (Canada) ensures the integrity of the medical diagnostic testing system by providing rigorous, objective, third-party evaluation according to international standards.[9]
- The Clinical and Laboratory Standards Institute (United States) sets standards and guidelines on a wide range of topics, including facility requirements.[10]
- The College of American Pathologists' (United States) Laboratory Accreditation Program ensures that laboratories meet or exceed regulatory requirements.[11]
- The United Kingdom National External Quality Assessment Service enables laboratories to fulfil quality goals and facilitate optimal patient care.[12]
- The Asia Pacific Laboratory Accreditation Cooperation includes accreditation bodies in the Asia Pacific region that accredit laboratories, inspection bodies and reference material producers.[13]
- The European co-operation for Accreditation (EA) is an organization of national accreditation bodies in Europe, each of which accredits laboratories in their respective countries.[14]

Generally, the design and construction of the cancer centre's laboratory must consider the following.[7,15]

Access: The laboratory should be secure and accessible only to permitted staff.

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Adjacencies: Ideally, the laboratory should have a direct connection to the surgical suite for the analysis of tissues obtained during surgery. If this is not possible, a connection through non-public corridors is acceptable. The increased use of digital images as well as POCT in the operating room may make the need for a direct connection less necessary. Other clinical areas that should be connected to the laboratory through non-public corridors include the critical care unit and outpatient clinics where specimens are collected. The morgue-autopsy area of the laboratory should also be accessible for the internal transfer of bodies through non-public corridors.

Size: The size of the laboratory will vary depending on the number and type of LMP services provided, the current and projected volume of specimens, the size of the laboratory equipment used and its space and other requirements, and the size and number of workstations needed for each department.

Flexibility: Knowledge of science, emerging technologies and evolving processes drive the design of laboratory space. Ideally, cancer centre laboratories should be built for flexibility, to accommodate evolving and new testing procedures. Flexible design may include organizing laboratory areas into pods or zones that can be modified depending on future needs and minimizing the use of fixed workstations. If it is unclear how to configure laboratory space to accommodate future growth, shelling in additional space that that can be adapted for future use should be considered. Another option is to locate the laboratory near "soft space," such as administration or storage space that is flexible and can be adapted to accommodate laboratory expansion.

Layout: The layout of the cancer centre laboratory should consider the following:

- The location of the central receiving area and administrative offices, which must reside on the perimeter and outside of the secure laboratory area.
- Support for efficient and effective flow between the central receiving area and the secure laboratory area.
- The incorporation of LEAN flow principles.
- The inclusion of designated areas for outpatient blood collection, the core laboratory, microbiology, cytology and histology laboratories, the blood bank, medical/scientific staff, staff facilities and shared services within the secure laboratory area. Some areas may require a contained space (e.g., a separate room) to minimize dust, vibrations, acoustic interference, and so on.
- The minimization of cross contamination. For more information see the *Cancerpedia: Infection Prevention and Control* chapter.
- The centralization of shared services in one area.
- The location of offices for technical specialists within their respective area.
- Similarity in the layouts, configurations and placement of equipment across laboratory areas and work zones, to minimize the need for staff to adjust to differences.
- Support for airflow from clean to less clean operations.
- The location of areas to change clothes, sanitize hands and remove waste, which should be at the laboratory perimeter and near the laboratory exit.
- Dedicated entrances into: the central receiving area for specimens, supplies and staff; the blood bank for hospital and courier staff; administrative offices and pathologists' offices for the public; and the morgue viewing area for the public.

Optimal use of space: There should be maximum access to utilities throughout the laboratory, including non-standard voltages. This will allow optimal use of space if areas need to be reconfigured.

Information and communication: Infrastructure is required to gather, document and communicate information in the laboratory. This includes information technologies, such as the LIS, which includes all laboratory information. And information and communication infrastructure is also needed to send and receive electronic digital images of specimens between the operating room and other hospitals and the laboratory, for analysis. Infrastructure to support these communications may include video links, standard and wireless telephones, internet connectivity and teleconferencing capabilities. Storage and support for bioinformatics may be required as well, which may have an impact on facility design and construction.

Automation: Laboratories should consider the use of automated and/or integrated instruments, where appropriate, as part of facility infrastructure. For example, automated instruments can be used to stain large

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volumes of slides and a robotic cover slipper can be used to apply glass coverslips on slides with stained tissue sections.

Safety design features: Many activities in the laboratory are inherently hazardous given that LMP personnel work with chemicals, and handle and store infectious material and toxins. The laboratory's physical infrastructure must incorporate safety design principles, which are outlined by ISO, established by many accreditation bodies, and included in building codes and other regulations.[6] Safety design features include, but are not limited to:

- Heating and ventilation systems to control air circulation and exchange, temperature and humidity. These systems should incorporate negative air pressure and inward directional airflow in high-containment areas, biohazard fume hoods, containment barriers, etc.
- Safety devices, such as hand washing sinks at entrances and exits to the laboratory and throughout the department, and emergency eyewash stations and showers for immediate access in case of an incident.
- Appropriate construction materials, finishes and coatings to maximize safety and infection control (e.g., walls, ceilings, floors, doors, bench tops, workstations, furniture, lighting, etc.).
- Appropriate and separate storage for all laboratory items that are used and disposed of (e.g., general supplies, laboratory coats, personal protective equipment, reagents paraffin blocks and slides, flammables, volatile and radioactive products, etc.).
- Biosafety equipment to contain infectious material or toxins (e.g., containment devices).
- Effluent treatment systems to avoid the release of untreated materials into sanitary sewers.

In addition to the design and construction considerations noted above, local, provincial/state and/or national regulatory bodies may stipulate facility requirements for laboratories in areas that include, but are not limited to:

- Electrical outlets for normal and emergency power use, including an uninterruptable power supply/source (UPS) and emergency generator backup to minimize laboratory downtime, maintain the LIS and ensure specimen integrity
- Appropriate electrical systems and voltage levels to support the full range of laboratory equipment
- A compressed gas infrastructure
- Access to staff facilities
- Meeting and teaching space
- Appropriate lighting to support specimen analysis

Special considerations for hematopoietic stem cell transplantation: Once a patient has been deemed eligible for hematopoietic stem cell transplantation, healthy and viable stem cells must be procured before treatment can proceed. Stem cells may be harvested from the bone marrow or the peripheral blood of either the patient (i.e., in an autologous transplant) or from an allogeneic donor. Stem cell harvesting from bone marrow occurs under general anaesthesia. Stem cell harvesting from peripheral blood occurs on an outpatient basis and may occur over the course of several days. A specialized apheresis laboratory is required to support stem cell mobilization and collection. In addition, a specialized cell processing laboratory is required to support stem cell cryopreservation and thawing, CD34+ enumeration, the determination of cell viability and other cell manipulation. For more information about the laboratory requirements related to apheresis and cell processing, refer to Leemhuis et al.[16]

Post-Analytic Phase

Entering the Data and Reporting the Results

Appropriate office space is required for clinicians and administrative staff to record data, such as test results. Ideally, this information is recorded and maintained electronically in an LIS.

Storing Specimens and Records

Appropriate storage facilities are required for both specimens and records. Storage facilities should prevent unauthorized access, loss, damage or deterioration due to temperature fluctuations, light, water, fire, vibration and other factors. Stored samples should be appropriately labelled.

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Point-of-Care Testing

Depending on the analytes being tested, POCT may have minimal physical infrastructure requirements (e.g. glucose meter POCT program). Other POCT testing performed either at the bedside or in an outpatient clinic may require sufficient space to house a small benchtop blood gas analyzer, as an example.

Regardless of where POCT occurs, the cancer centre must ensure that POCT equipment and supplies are used appropriately and safely. Quality assurance for a robust POCT program includes ensuring that operators – who are typically non-laboratory personnel –are trained and competent, that quality control regimens are in place, and that equipment is in good working order and handled appropriately. Locally developed operating procedures for POCT equipment are required, including clear instruction on reference or therapeutic ranges and critical results protocols, cleaning and disinfecting devices using infection control standards, and ensuring that consumables are stored appropriately.

5. HUMAN RESOURCES

The laboratory medicine and pathology service is provided by a range of professionals that include medical, technical and scientific personnel. All members of the LMP team focus their professional skills and expertise on accurately diagnosing and monitoring cancer.

This section begins by describing the range of LMP human resources required in a cancer centre. While the core functions required by cancer centres are standards, the job titles and education requirements of individual staff may vary by jurisdiction and scope of practice.

Medical Expertise

Different countries use different terms to refer to medical professionals who analyze prepared specimens, conduct specialized tests, and diagnose the presence and spread of disease. For example:

- In Canada and the United States, medical experts who analyze specimens and diagnose disease are called laboratory medicine specialists and pathologists. In cancer centres, pathology includes two major areas: anatomic and clinical. Anatomic pathology diagnoses disease through the gross, microscopic, histochemical, immunologic and molecular examination of organs, tissues and body fluids. Clinical pathology diagnoses disease through the laboratory analysis of bodily fluids and tissues using chemistry, microbiology, hematology and molecular pathology.
- In Europe, the title applied to medical experts who analyze specimens and diagnose disease varies by country and may include clinical pathologist, laboratory medicine specialist, clinical analyst and clinical/medical biologist. The training and scope of practice of these professionals may vary. Depending on the jurisdiction, an individual with a medical degree, pharmacy doctorate or related PhD can take additional specialty training to diagnose disease based on laboratory results.

The number of laboratory medicine specialties required in a cancer centre depends on the volume of patients and the types of cancer being treated. Generally, the centre needs to have:

- ***Anatomic laboratory medicine specialists/pathologists***: These individuals include some generalists and a higher number of certified subspecialists. The types of subspecialists required by a cancer centre depends on the types of patients being treated. Each subspecialist requires a critical mass of patients to ensure ongoing clinical proficiency.
- ***Clinical laboratory medicine specialists/pathologists***: Generally, these individuals work with laboratory departments.
- ***Clinical laboratory genetic specialists***: These individuals analyze the genetic make-up of patient samples.

Some jurisdictions recognize ***pathology assistants*** who work under the direction or supervision of a licensed pathologist. The scope of their practice may vary depending on the jurisdiction in which they work. Responsibilities may include conducting a preliminary review of tissue (i.e., gross examination), selecting representative pieces of tissue to be processed and examined by the pathologist, procuring tissue for biobanking, preparing tissue for testing, engaging in non-forensic autopsies and other duties.

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Pathology assistants are a relatively new professional group that are common in some countries. Countries that do not use them have other professionals, such as pathology residents, pathologists and technical laboratory staff, to perform the tasks noted above.

Technical Expertise

Technical staff play an increasingly significant role in the cancer centre's LMP service. These staff usually conduct functions in the pre-analytical and analytical phases.

The scope of practice of professionals with technical expertise may vary, depending on the laws set by the national or subnational jurisdictions in which they work. The job titles and specific responsibilities of these individuals may also vary by organization. Generally, there are two levels of LMP staff with technical expertise:

- ***Advanced level of technical medical laboratory training***: These individuals are trained in an accredited school of laboratory medicine and are certified to practice through a national or subnational licensing body. They may have additional specialty graduate diploma training in such areas as diagnostic cytology, molecular genetics, cancer cytogenetics and immunohistochemistry. Depending on the jurisdiction and their responsibilities, individuals with an advanced level of technical medical laboratory training may be known as medical laboratory technologists, medical laboratory scientists, biomedical scientists or clinical laboratory technologists.
- ***General level of technical medical laboratory training***: These individuals may be trained in an accredited school of laboratory medicine or receive on-the-job training where they work. Depending on the jurisdiction and their responsibilities, individuals with a general level of technical medical laboratory training may be known as medical laboratory technicians, medical laboratory assistants or phlebotomy technicians (i.e., professionals who specifically collect blood).

A cancer centre's LMP service should have technical staff who are generalists, but who also have specialty training. The number and types of technologists required depends on the volume of patients and the type of testing that the cancer centre conducts.

In addition to technical staff having formal or on-the-job education training, the LMP service should ensure that targeted training is provided to operate hazardous equipment and manipulate hazardous agents.

Human Resource Requirements

The number of staff with medical, technical and scientific research expertise required by a cancer centre varies depending on the volume of patients treated, the types of LMP testing conducted and the role of the centre in the jurisdiction in which it is located. For example, a cancer centre that provides specialized testing to a wide catchment area may need more specialized staff than a centre that serves a smaller local population. Human resources also include the appropriate number of staff who are trained to provide oversight of the cancer centre's POCT program.

Table 1 presents an overview of LMP human resource requirements by activity.

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Table 1: Laboratory Medicine Human Resource Requirements

	Activity	Goal	HR Requirements
Pre-Analytic	Collecting the Specimen	Collect specimens from patients for testing.	• Laboratory technicians may extract blood and other samples from inpatients or patients in outpatient clinics (e.g., phlebotomy technicians). Generally, most specimens are collected by non-LMP service staff (e.g., surgeons in the operating room, surgeons or other professionals in biopsy clinics, professionals at the bedside of patients or in outpatient clinics, professionals in community-based clinics). • The number and type of staff required depends on the volume of patients and the types of testing conducted by the cancer centre.
	Receiving the Specimen at the Laboratory	Receive all specimens for distribution to appropriate LMP staff.	• Generally, specimens are transported to the laboratory by non-LMP service staff. • LMP technicians. • The number and type of staff required depends on the volume of patients and the types of testing conducted by the cancer centre.
Analytic	Processing the Specimen for Analysis	Prepare the specimens for analysis and final diagnosis by the pathologist.	• Staff to conduct gross examinations of specimens: a) pathology assistants; b) pathology residents; and/or c) pathologists • Technical staff to process specimens for analysis, including those with: a) an advanced level of technical medical laboratory training, such as generalists and specialists in diagnostic cytology, molecular genetics, cancer cytogenetics, immunohistochemistry and other specialties; b) a basic level of technical medical laboratory training. • The number and type of staff required depends on the volume of patients and the types of testing conducted by the cancer centre.
	Analyzing the Specimen and Interpreting Test Results	Analyze the specimens, review data and clinical information, and determine the final interpretation.	• Anatomic pathologists: generalists and subspecialists • Clinical pathologists • Clinical scientists, to advise pathologists and/or medical oncologists on specialized diagnostic and treatment approaches, as required. • The number and types of pathologists required depends on the volume of patients and the types of testing conducted by the cancer centre.
Post-Analytic	Entering the Data and Reporting the Results	Enter laboratory results data and report results to requesting clinicians.	• Clinical/administrative staff with training in medical terminology. • The number of staff required depends on the volume of patients and the types of testing conducted by the cancer centre.
	Storing Specimens and Records	Store specimens and records.	• Technicians. • Technologists.
LMP Management		Manage the laboratory.	• Laboratory medical director, responsible for the delivery of clinical services. Ideally, the medical director is a pathologist. • Executive director, responsible for the administrative management of the laboratory, and technical and administrative activities. • Chief of each laboratory department. • Director/manager/supervisor for each laboratory department. • Quality manager/supervisor for the laboratory. • Managers, as required (e.g., for information technology and the LIS, finance, business analysis, etc.)
Other		Educate clinicians on test ordering, collecting specimens and appropriate utilization. Educate patients about test results.	• Technologists with the assistance of pathologists, as required.

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6. INFORMATION MANAGEMENT

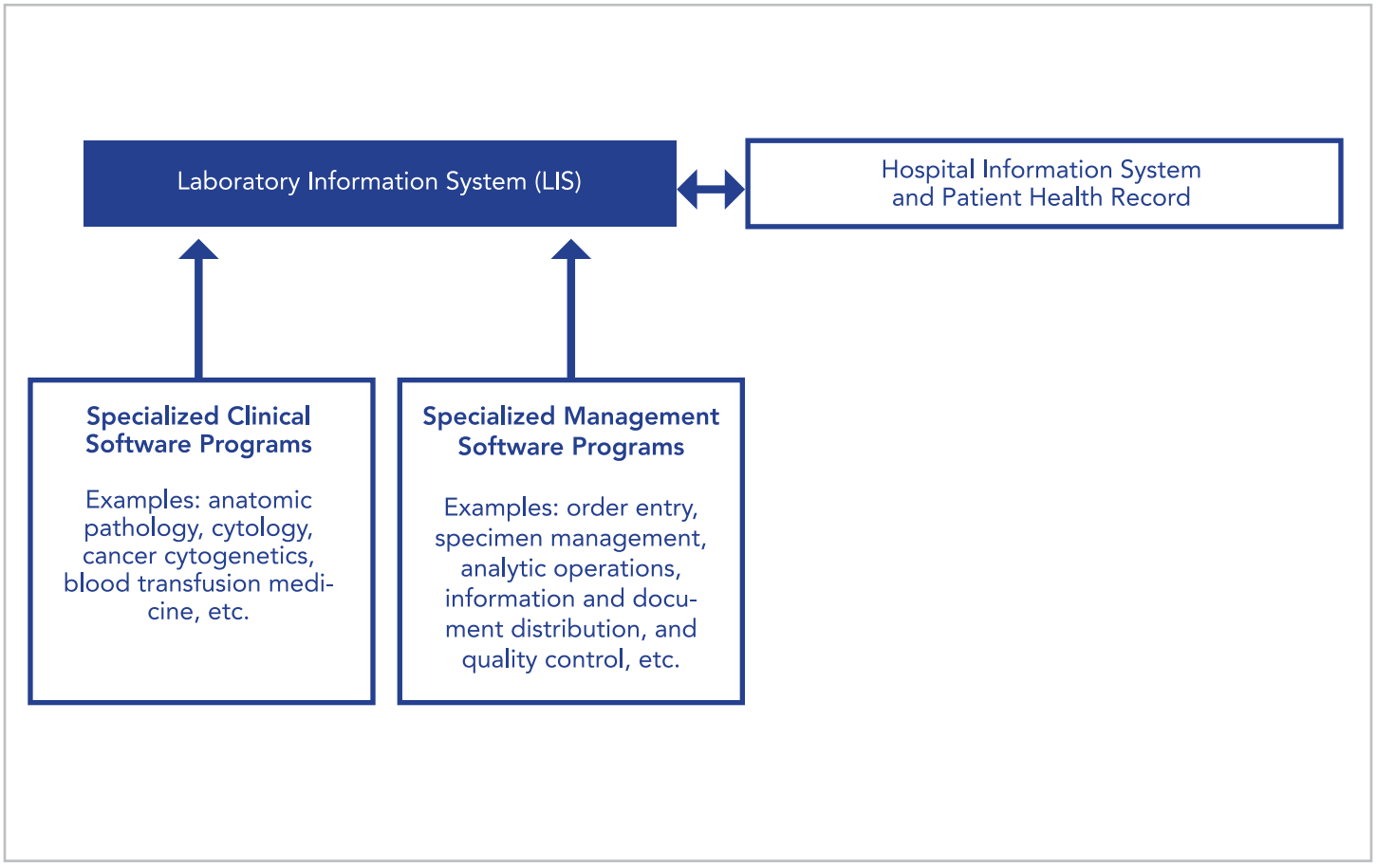
The cancer centre needs a corporate-wide information management (IM) infrastructure that provides an overarching umbrella for the LMP-specific IM infrastructure. Ideally, this corporate-wide and function-specific IM infrastructure is electronic and fully integrated.

Typically, the LMP-specific IM infrastructure has one main information system, as illustrated in Figure 2. The LIS is a computerized laboratory and management information system that incorporates a series of specialized clinical and management software programs to collect, process, store and manage data from the pre-analytic, analytic and post-analytic phases. The LIS integrates a wide range of information on patients, including demographics, tests ordered, samples collected, specimens processed, test findings, complex scientific analyzes to inform the pathology diagnosis and the report of results. Ideally, the LIS includes: voice recognition capability; a bar code labelling system that links patients with their samples, data findings and results; structured reporting; tracking capabilities; and so on.

Ideally, a cancer centre should have an electronic LIS. It is very difficult for a manual, paper-based system to handle a large volume of interrelated information effectively, accurately and in a timely manner. The LMP service should oversee the LIS and its software applications so that LMP subject matter experts can shape the information required for an effective and timely LMP service. Some in-house information technology expertise is required to conduct basic programming and support specialized software systems. For more information, see the Cancerpedia: Equipment and Technology chapter.

The LIS should be integrated with the cancer centre's hospital information system and patient health record. Links with the centre's hospital information system supports such activities as the requisitioning of tests, the reporting of results and monitoring quality. Links with the patient health record system supports the patient and the healthcare team by making critical and timely pathology diagnoses available to guide treatment decisions.

Figure 2: Information Management Infrastructure for Laboratory Medicine and Pathology



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The cancer centre may need to support electronic linkages with other facilities. For example:

- If the cancer centre is a major receiving site that performs specialized LMP tests for smaller centres or hospitals, a common integrated LIS system, web access and digital imaging portals should exist at all sites. Telepathology – which transmits digital images of pathology samples – allows physicians in rural and remote hospitals to consult with specialist pathologists in cancer centres for more challenging cases.
- If the cancer centre is part of a subnational or national cancer system and registry, the centre will need an information management system that links to the larger cancer system. For example, hospitals and laboratories in Ontario, Canada transfer patient and tumour information for cancer and cancer-related laboratory reports to Cancer Care Ontario using the Patient Information Management System (PIMS). The information – which feeds into the Ontario Cancer Registry – is used for various purposes, such as planning, disease surveillance and research.[17]

In addition to tracking and documenting clinical and management information, the LIS should be used to track and improve performance.

D. MANAGEMENT

7. LEADERSHIP

The laboratory medicine and pathology service should have a joint clinical-administrative leadership model. Clinical leaders are accountable for quality care, clinical management and processes, and clinical staff performance. Administrative leaders are accountable for effective and efficient management and operational control processes, business techniques, capital issues, financial performance and project management. The clinical-administrative leadership team should have a common vision, a unified program and business plan with agreed-upon goals, and a commitment to work together to achieve common objectives in clinical care, education and research.

The typical core LMP service leadership team should include the following:

- A clinical director and an administrative or executive director should co-lead and be held jointly accountable for the overall LMP service.
- Each laboratory department should have a departmental chief and an administrative or technical director/manager/supervisor working jointly to oversee the operations of their respective department (e.g., clinical biochemistry, clinical hematology and transfusion medicine, clinical microbiology, anatomic pathology, POCT, etc.).
- A quality manager/supervisor should ensure that quality management processes are being implemented and quality issues are being addressed. The International Laboratory Standards (ISO 15189) requires laboratories to have a designated quality manager who reports to laboratory leadership at the level at which decisions are made.[6]

The membership and size of the core leadership team may increase depending on the number of specialized departments, the number and complexity of tests performed at the cancer centre, and the role of the cancer centre as a referral centre. For example, if the centre's LMP service has high internal volumes as well as significant external referrals into the centre, the leadership group may include managers with expertise in areas such as:

- Communication and education, to ensure appropriate ordering of tests and use of referral processes
- Laboratory information management/technology, to support the LIS, digital imaging and telepathology
- Finance and business analysis, to enable appropriate overall and case costing
- Patient flow systems, to support appropriate care pathways for inpatients, outpatients and external referrals

The leadership team should be supported by a committee structure to facilitate the stewardship of the LMP service and its various components.

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8. ACCREDITATION OPERATING STANDARDS AND GUIDELINES

Cancer centres must meet accreditation operating standards and guidelines that have been established by their national accreditation body.[18] Many countries have health service accreditation programs, whereas others adopt or adapt the programs of other countries. These accreditation bodies set out operational standards and guidelines to support a safe and effective hospital and may also include requirements for a laboratory medicine service.

Various accreditation and standard-setting organizations specifically address LMP operating requirements, including POCT. At the international level, these include:

- The International Organization for Standardization, a worldwide federation of national standards bodies that has developed requirements of quality and competence for medical laboratories.[6]
- The AABB (formerly known as the American Association of Blood Banks), which develops standards and has an accreditation program that assesses the quality and operational systems for the safe collection, processing, testing, distribution and administration of blood, blood products and cellular therapy products.[19]

Examples of national accreditation and standard-setting bodies for medical laboratories – many of which have an international scope – include the following:

- The College of American Pathologists (CAP), which has a laboratory accreditation program with almost 7,500 CAP-accredited laboratories in 50 countries. CAP accreditation is widely recognized.[20]
- The United States' Joint Commission, which is an independent, not-for-profit organization that accredits and certifies healthcare organizations and programs, including laboratory services.[18]
- Accreditation Canada, which is an independent, not-for-profit organization that accredits health organizations across the country, and includes standards for biomedical laboratory services, laboratory and blood services, and blood bank and transfusion services.[19]

For additional laboratory accreditation bodies, see the International Laboratory Accreditation Cooperation, an international group of laboratory and inspection accreditation bodies[20], and the Asia Pacific Laboratory Accreditation Cooperation, a group of accreditation bodies in the Asia Pacific region.[21]

The LMP service in a cancer centre should meet nationally or internationally recognized accreditation standards that are assured though independent peer review, whichever are more stringent. In addition, the LMP service must comply with the laws, regulations and licensing requirements of the jurisdiction in which it is located. The following is not meant to reflect all of the complexities of accreditation standards and guidelines, given that detailed requirements and wording will vary by jurisdiction; rather, the information below presents broad areas that tend to be required for LMP accreditation.[22]

Services

Accreditation standards and guidelines for LMP typically include requirements in the pre-analytic, analytic and post-analytic phases.

Pre-Analytic Phase

- A scheduling system handles requests using standard forms and processes for regular and urgent requests.
- Standard procedures are used to collect the right samples using the appropriate methods; samples are clearly labelled, linked to the patient and packaged for transport.
- Samples are transported appropriately and in a timely manner; a process exists to handle specimens after hours.
- Samples are appropriately recorded, identified, accepted/rejected for assessment, and stored and triaged for analysis.

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Analytic Phase

- Samples are processed appropriately and in a timely manner.
- Standard procedures are used to determine appropriate examinations, and to analyze specimens.
- The appropriateness and quality of the analysis are evaluated, and quality issues are addressed quickly.
- A standard laboratory report is used that includes appropriate, clear and well-presented information.

Post-Analytic Phase

- Results are verified and authorized for release.
- Reporting turnaround times are used, including the reporting of critical test results.
- Standard processes are used to communicate results to authorized individuals internal and external to the cancer centre.
- Specimens are stored in appropriate environmental conditions that are maintained even in the event of power failure.
- Specimens are disposed of and records are deleted in accordance with appropriate legislative and regularly requirements.
- Records of all results and reports can be easily and quickly accessed and are stored in accordance with appropriate legislative and regulatory requirements.

In addition, there are specific accreditation standards and guidelines for LMP in relation to a cancer program, such as effective LMP service co-ordination and the alignment of activities to support clinical providers, departments, services and organizations (e.g. effective communication, attendance at regular clinical team meetings and rounds, consultation on appropriate tests and interpretation of results).

Human Resources

Accreditation standards and guidelines for LMP human resources require an appropriate mix and number of fully-qualified and licensed staff to meet expected responsibilities. Education, training and professional development opportunities are provided to all laboratory staff – including physicians – to ensure ongoing competence. For more information, see the *Cancerpedia: Education* chapter.

Physical Facilities and Equipment

Accreditation standards and guidelines for LMP physical facilities and equipment typically include requirements to: meet all planning, design and construction requirements set by subnational, national and international regulatory bodies; ensure that the laboratory's construction, design, layout and physical environment enable tasks to be carried out effectively, efficiently and safely; ensure that the layout of required laboratory equipment optimizes workflow, infection control and a safe working environment; ensure that appropriate equipment and supplies are available, in good condition and regularly inspected and maintained; and so on.

Quality and Safety

Accreditation standards and guidelines for LMP quality and safety tend to focus on requirements to have:

- An effective laboratory safety program
- Ongoing staff education on quality and safety, which includes safe work practices, and identifying and handling hazards
- A quality management system that includes monitoring and improving processes and outcomes
- Protocols for ongoing safety, such as infection control, handling of hazardous waste and substances, etc.

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9. POLICIES, PROCESSES AND PROCEDURES

Policies, processes and procedures reflect different and interconnected levels of activity.

- Policies are the standards and guidelines of the cancer centre that govern how it operates. The centre's operating policies should reflect accreditation operating standards and guidelines. Policies drive processes and procedures.
- Processes set out what the cancer centre will do to achieve its policies. Processes usually identify who is responsible for performing the process (e.g., department), and the major functions or tasks that will be performed. Processes are high-level actions that drive specific procedures.
- Procedures identify the specific steps that will be taken to perform a task, who will do them and when.

Cancer centres must establish policies, processes and procedures and make them readily available to all LMP service staff with training, as required. Standard operating procedures (SOPs) should be regularly assessed for their ongoing relevance and effectiveness (i.e., annually at a minimum), and updated, as required. Document control is critical to ensure that the most updated versions of policies, processes and procedures are being used. Although document control can be both manual and electronic, an electronic system is preferred as the number of SOPs increases.

Examples of areas in which LMP policies, processes and procedures must be developed include, but are not limited to, the following:

Pre-Analytic Phase

- Scheduling of sampling procedures; emergency sampling procedures; positive patient identification; translation and interpretation services
- Patient instructions before and after specimen collection; informed consent to take a sample
- Process to extract a sample; sample labelling and handling; sample preparation for transport; transport responsibilities and procedures
- Receiving samples in the laboratory (i.e., during and after hours), including labelling and tracking; acceptability of specimens; specimen distribution to the appropriate laboratory department for testing; specimens requiring immediate analysis
- Documentation of information in the LIS

Analytic Phase

- Gross examination; preparation of blood/body fluid samples and tissue samples; biobanking
- Quality control checks before pathologist review
- Analysis of samples; interpretation of test results
- Documentation of information in the LIS

Post-Analytic Phase

- Communication of test results; pathology report content and presentation
- Documentation of information in the LIS; elimination of excess tissue
- Labelling of stored samples; storage of samples (i.e., diagnostic, research); storage of records

Point-of-Care Testing

- Requirements for all activities in the pre-analytical, analytical and post-analytical phases

Safety

- Infection prevention and control; biosafety procedures; use of personal protective equipment
- Emergency incident procedures; violence and harassment; safety codes
- Disposal of materials

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Adverse Events

- Disclosure of adverse events; incident reporting

Equipment and Supplies

- Equipment and supply availability; maintenance procedures

Infrastructure

- Access to and exit from the laboratory
- Storage of clean and contaminated items
- Electrical failure; light or fan system failure

Human Resources

- Responsibilities of all LMP personnel
- Staff competency testing and associated documentation
- Continuing education requirements

Students, Other

- LMP student practice; observers in the LMP service

10. MANAGEMENT OF SPECIMEN FLOW

Cancer centres must manage the smooth flow of patient specimens into and within the laboratory, as well as the flow of test results out of the laboratory and to the requesting clinician. As the specimen moves from one point of contact to the next, centres must ensure that effective referral processes are in place and that formal handoffs occur between the most responsible staff at each transition point.

A cancer centre's LMP service must consider both internal and external flow, including;

- Internal flow within the cancer centre: When a specimen is collected in the cancer centre, the samples must flow seamlessly into the centre's laboratory. The laboratory report must then flow back to the requesting clinician in the centre.
- Internal flow within the LMP service: There must be a smooth flow within the LMP service.
- External flow: When a specimen is collected in other hospitals or in community-based practices, the samples must flow seamlessly from these external locations into the centre's LMP service. Similarly, there must be a smooth external flow of the laboratory report back to the requesting clinician in these external locations.

Table 2 details the management of patient specimen flow by LMP phase.

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Table 2: Management of Specimen Flow

	LMP Phase	Management of Specimen Flow
Pre-Analytic Phase		
1.	Ordering the Test/Requisition	• Test order sent to laboratory.
2.	Collecting the Specimen	Internal to the cancer centre: • Specimen is collected in the operating room, biopsy room, at the inpatient bedside or in an outpatient clinic. • The surgeon, clinician and/or technical staff handle the specimen appropriately to ensure specimen integrity. External to the cancer centre: • Specimen is collected in another hospital or setting, in the operating room, biopsy room, at the inpatient bedside or in an outpatient clinic. • Specimen is collected in a community-based practice. • In all instances, the surgeon, clinician or technical staff handle the specimen appropriately to ensure specimen integrity.
3.	Handling and Transporting the Specimen	Internal in the cancer centre: • Technical or other designated staff follow established processes for transporting specimens to the laboratory. These processes include specific requirements for transporting specimens taken from surgical patients, inpatients and outpatients. External to the cancer centre: • The clinician working in another hospital or community-based practice follows established processes for transporting specimens (i.e., physical and virtual) to the cancer centre laboratory.
4.	Receiving the Specimen in the Laboratory	• Central receiving accepts or rejects specimens for analysis using standard processes. • Central receiving triages specimens to the appropriate laboratory station for testing using standard processes. • Central receiving has a process for specimen deliveries after hours.
Analytic Phase		
5.	Processing the Specimen for Analysis	• Pathology staff review patient information and assess the specimen to determine if it is acceptable for the requested test (e.g., integrity of specimen; sufficient volume to support testing). • Pathology staff conduct a preliminary review of the specimen and, when appropriate, obtain samples for research purposes in the biobank. • Technical staff prepare tissue samples. • Technical staff assess and document microscopic findings from slides.
6.	Analyzing the Specimen and Interpreting the Results	• Pathologist analyzes the prepared tissue samples and correlates findings from the tissue review with the patient's clinical information. • Pathologist may order additional studies for information to aid in diagnosis. • Pathologist documents the final pathology diagnosis based on all test results.
Post-Analytic Phase		
5.	Entering the Data and Reporting the Results	• All data on the patient, specimens and test results is entered into the LIS. Internal to the cancer centre: • Laboratory medical/technical staff follow established processes for communicating test results and the pathology diagnosis/report to the requesting surgeon/ clinician in the cancer centre External to the cancer centre: • Laboratory medical/technical staff follow established processes for communicating the pathology diagnosis/report to the requesting surgeon/clinician in other hospitals or community-based practices.
6.	Storing Specimens and Records	• Excess tissue is stored and/or disposed of according to legislative requirements. • All specimens and records are stored for an appropriate amount of time according to legislative requirements.

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11. DOCUMENTATION AND DATA-INFORMED MANAGEMENT DECISIONS

Cancer centres must collect and analyze standard LMP information to ensure that:

- The handling and analyzing of patient samples are consistent with the policies and procedures of the organization
- LMP resources are being used effectively and efficiently
- LMP practices are safe

Documentation is required throughout the LMP pathway. Given that the amount of data collected can be overwhelming, management should develop a minimum data set with clearly defined key indicators to monitor activities and processes, and identify areas to improve performance. Indicators should be analyzed to support data-informed management decisions, and management tactics implemented to mitigate risks and make improvements. Improvement can be assessed in various ways; for example, the centre can focus on internal performance improvements, compare its performance in relation to external standards or compare its performance in relation to external peer group benchmarks.

Table 3 presents a suite of LMP management indicators that might be considered for a cancer centre's minimum data set. Additional indicators may depend on local circumstances. Table 3 also presents potential management analyzes targeted at improving performance.

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Table 3: Examples of Laboratory Medicine and Pathology Indicators and Management Analysis

Area	Indicators	Management Analysis
Ordering Tests	• Number of tests ordered by source and location (e.g., cancer centre operating room, inpatient unit, outpatient clinic; other hospital; community-based provider).	• Profile of test sources, including analysis of internal/ external catchment and variations over time.
Specimen Volumes	• Number of specimens. • Number of specimens deemed unacceptable by reasons and source (e.g., not enough volume, integrity breached due to transport/ environmental conditions, leakage etc.). • Number of urgent specimens received in a defined time period.	• Specimen volumes over time along with utilization and cost analysis (i.e., financial, human, capital, operating), to identify resource gaps and opportunities for efficiencies. • Analysis of unacceptable specimens, reasons and improvement tactics. • Analysis of impact of urgent cases on LMP resources and scheduling, and improvement tactics.
Specimen Flow Within the Laboratory	• Number of specimens delivered after hours that are delayed or not received by the laboratory. • Start and end times of each point in the specimen flow, beginning with central receiving and ending with the pathology report received by requesting clinician.	• Analysis of after-hours issues, and improvement tactics. • Analysis of delays and blockages in the flow of specimens, and improvement tactics.
LMP Quality Practices	• Percentage of samples prepared correctly. • Percentage of samples with correct microscopic analysis. • Completeness of pathology reports. • Compliance with quality and safety regulations and requirements.	• Assessment of correct sample preparation, and improvement tactics. • Assessment of correct microscopic analysis, and improvement tactics. • Identification of incomplete report issues, and improvement tactics. • Rate of compliance with quality and safety regulations and requirements.
Report Communication	• Percentage of reports communicated within acceptable wait times, including reports on urgent cases.	• Analysis of reporting wait times against targets, and improvement tactics, as required.
Specimen and Records Storage	• Number of stored specimens compromised due to storage issues. • Disposal of excess tissue and specimens when they have met regulatory retention requirements.	• Identification of storage issues that compromise specimen integrity, and improvement tactics. • Analysis of long storage times to free up space.
Use of LMP Resources	• Volume of equipment and supplies used in the LMP service in relation to activity.	• Volumes, resource utilization and costs (i.e., financial, human, capital, operating), resource gaps and opportunities for improved efficiencies without compromising the clinical LMP service.

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E. QUALITY

Quality performance in laboratory medicine and pathology is critical given that an estimated 85 per cent of decisions about diagnosis and treatment are based on laboratory test results.[21] Studies have shown that there is an estimated 6.4 to 12 per cent risk of inappropriate care (i.e., adverse events) due to laboratory errors, and that laboratory errors result in patient care problems in about 26 to 30 per cent of cases.[22]

Multiple opportunities exist for quality to be compromised in an LMP service. It appears that most errors occur in the pre-analytical and post-analytical phases:[23]

- Pre-analytical errors range from 46 to 68.2 per cent and include inappropriate test requests, order entry errors, misidentification of patients, inappropriate containers, inadequate sample collection and transport, inadequate sample/anticoagulant volume ratios, insufficient sample volumes, sorting and routing errors, and labelling errors.
- Analytical errors range from seven to 13 per cent and include equipment malfunctions, sample mix-ups/interferences, undetected failures in quality control and procedures not followed.
- Post-analytical errors range from 18.5 to 47 per cent and include reporting failures, erroneous validations of analytical data and improper data entry.

Significant international efforts have been made to improve safety in medical laboratories. As noted earlier, the International Organization for Standardization recently updated its medical laboratory requirements for quality and competence, which were first published in 2003. The comprehensive ISO 15189:2012 standard includes management and technical requirements. It has been adopted or adapted into national standards for medical laboratories in many countries.[24] The standard was developed by representatives from 33 countries representing regions across all continents except Antarctica, and has been totally or partially accepted by medical laboratories in more than 55 countries.[25]

The following section addresses important considerations for quality performance in the LMP service.

12. STANDARDS, GUIDELINES AND BEST PRACTICES

LMP quality standards, guidelines and best practices are common to all of the work conducted by the LMP service and are not specific to cancer care. Some cancer-specific LMP standards and guidelines may exist for diagnosing cancer. The standards, guidelines and best practices used by a cancer centre may originate from different sources, such as international, national and subnational organizations and bodies. Although cancer centres may develop local best practices, generally these should align with the national and subnational standards and guidelines of the jurisdiction in which the cancer centre is located.

Human Resources

A quality LMP service must fulfil all human resource requirements and ensure that its staff meet ongoing quality standards. All healthcare professional groups develop professional care standards and recommended practices for their members, including ongoing competency and continuing education. Examples of professional bodies that focus on LMP human resource standards, practices and education include the following:

Medical

- Australia: Royal College of Pathologists of Australia[26]
- Canada: Canadian Association of Pathologists[27]
- Europe: European Society of Pathology; European Federation of Clinical Chemistry and Laboratory Medicine[28,29]
- International: World Association of Societies of Pathology and Laboratory Medicine; International Federation of Clinical Chemistry and Laboratory Medicine[30,31]
- North America: United States and Canadian Academy of Pathology[32]
- United Kingdom: The Royal College of Pathologists (United Kingdom)[33]
- United States: College of American Pathologists; American Association of Pathologists' Assistants[34,35]

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Technical
- Australia: Australian Institute of Medical Scientists[36]
- Canada: Canadian Society for Medical Laboratory Science; Canadian Association of Medical Laboratory Educators[37,38]
- Kuwait: Kuwait University Health Sciences Center[39]
- New Zealand: New Zealand Institute of Medical Laboratory Science[40]
- United Arab Emirates: Higher Colleges of Technology[41]
- United Kingdom: Institute of Biomedical Science[42]
- United States: American Society for Clinical Laboratory Science; American Medical Technologists; Clinical Laboratory Management Association[43-45]

Facilities

The cancer centre must have an adequate and appropriately designed LMP facility infrastructure to meet its needs. From a quality perspective, the infrastructure must meet building and biosafety standards and requirements set by national and subnational bodies. In addition, all equipment, reagents and supplies used should meet quality standards.

Diagnostic Management

Standards and guidelines for LMP diagnostic management are based on evidence or expert consensus. These can be developed by LMP-specific organizations or by larger health bodies. A number of organizations make available a wide range of cancer-related standards and guidelines, including those for LMP. For more information, see the Cancerpedia: Clinical Management chapter.

Work Practices

Cancer centres should implement quality LMP work practices within and across the analytic phases and in collaboration with clinicians in the cancer centre and beyond.

Figure 3: Examples of Quality Performance Within Each LMP Phase

Pre-analytic Phase
- Appropriate tests are ordered and the test orders are entered correctly (e.g., computerized order entry).
- The patient is correctly identified (e.g., wristbands, unique identifier), the correct sample is collected, and the collection processes are appropriate (e.g., right containers and equipment, sufficient sample volume, sterile conditions, right barcoded labels, etc.).
- Specimens are transported appropriately and in a timely fashion.
- When the laboratory receives specimens, they are correctly registered, labelled, sorted and routed to the appropriate area.
- Medical and hospital staff have the training to meet pre-analytic requirements.

Analytic Phase
- Specimens are processed correctly using standard procedures.
- Correct testing methods are used.
- Appropriate and sufficient supplies and equipment are available.
- Equipment is well maintained and functions appropriately.
- Laboratory staff are qualified and meet professional competency standards.
- Laboratory examination results are interpreted correctly using appropriate standards and results/reports are of high quality.
- The laboratory and each laboratory area meets the operating standards and guidelines required by relevant regulatory and accreditation bodies.

Post-Analytic Phase
- Reports of laboratory results meet quality standards and guidelines.
- Reports are clear, completed correctly and communicated to the referring clinicians within established timelines.
- Data is entered correctly.
- Laboratory test results are used appropriately to make final diagnostic and treatment decisions.
- Samples and records are stored appropriately.

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Within and Across the Analytic Phases

Quality work practices must occur within each LMP analytic phase. Figure 3 presents illustrative examples of quality performance within each phase.

Quality practices are also required across the phases. A great deal of effort is needed to plan, prepare and co-ordinate LMP services so that patients receive the right pathology diagnosis in a timely fashion and so that resource use (i.e., human, technological, facility and financial) is optimized. Poor flow results in delays in diagnoses, increased waits, high levels of patient and staff stress, and suboptimal resource use.

The use of process improvement methodologies is a major tactic for improving LMP quality and efficiency. One common approach is Lean methodology. Front-line staff use a structured process to define value, map work steps, and identify and remove unnecessary steps in their work.[46] A second common approach is Six Sigma. Six Sigma uses quantified value targets and identifies and removes the cause of defects or errors to eliminate these defects and minimize variability.[47] Aspects of both approaches can be used for quality improvements.[48] For more information, see the *Cancerpedia: Quality* chapter.

Attention to process and process improvements in laboratories is critical. LMP processes have become more complex with the significant shift from inpatient to outpatient cancer services. The fact that many clinicians and outpatient clinics feed into the LMP service highlights the importance of SOPs for ordering tests and verifying and tracking patients, measuring and monitoring the time of each step in the testing process, and turning around pathology results in a timely manner.

Many programs are available to help hospitals improve the quality and efficiency of the LMP service. Examples include:

- The College of American Pathologists' CAP 15189 Quality Management Program, which takes a process management approach and provides accreditation to the international ISO quality standard for medical laboratories.[21]
- The Institute for Quality Management in Healthcare, which provides quality management services along with support for accreditation to meet the ISO 15189 standard.[9]

In addition, numerous international and national bodies have developed extensive guidelines and recommendations that centres can use to develop safety protocols in such areas as infection prevention and control, universal precautions, and handling of hazardous biomedical waste and substances:

- World Health Organization[49]
- Australian Commission on Safety and Quality in Health Care[50]
- Centers for Disease Control and Prevention[51]
- European Centre for Disease Prevention and Control[52]
- Infection Prevention and Control Canada[53]

In Collaboration with Clinicians in the Cancer Centre and Beyond

A number of LMP quality work practices must be developed and implemented in collaboration with clinicians in the cancer centre and beyond. Three key practices are described below.

The LMP service requires a ***priority rating system, with associated turnaround times*** to guide timely access to laboratory services. The system should:

- Define what is meant by an LMP wait (e.g., time from when a tissue sample is taken to when the requesting clinician receives the pathology diagnosis).
- Establish standard priority levels (e.g., urgent to least urgent), develop standard clinical assessment criteria for each priority and identify recommended wait time targets for each priority. Targets may vary by the type of test.

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In addition to a total turnaround time target, targets should be set for each step of the LMP pathway (e.g., time from when a tissue sample is taken to when the laboratory receives it, time it takes to analyze a sample, and so on). This will enable the LMP service to identify exactly where delays are occurring and address issues. Clinicians in the cancer centre should be involved in developing the LMP priority rating system. All clinicians within and outside of the cancer centre who request test results should be made aware of, and understand, the rating system and associated turnaround times.

Multidisciplinary cancer conferences (MCCs) – also known as multidisciplinary meetings and tumour boards – are a quality practices that bring together a range of healthcare providers to develop and monitor treatment plans. For more information, see the *Cancerpedia: Clinical Management* chapter.

LMP reporting includes the full range of ***communication and reporting*** between requesting clinicians and laboratory and pathology staff. Effective communications and accurate and timely reporting of results are critical. Patient death or serious injury resulting from failure to follow-up or communicate laboratory, pathology or radiology test results is a serious reportable event in healthcare, as defined by the American-based National Quality Forum.[54] In addition to failing to follow up or communicate results, presenting results inappropriately or in a way that the clinician cannot understand can lead to the inappropriate interpretation of test results, misdiagnoses and wrong treatments.

Generally, a patient's LMP record includes objective data in the form of the detailed results of all tests taken (e.g., immunology, immunochemistry, molecular, cytogenetic, flow cytometry, etc.), as well as a laboratory report that interprets these test results, provides a diagnosis, and may suggest an optimal course of treatment based on the anatomic pathology analysis.

Verified laboratory test results are typically entered into the LIS. Results and reports should only be released and received by those authorized to do so. Protocols to communicate clinical laboratory test results vary by jurisdiction and the type of test.

The structure of the LMP record, how laboratory test information is presented, and the structure, format and content of the report are critical. Generally, each test has a reference interval, which represents a pre-determined range of normal values against which a patient's test results are compared. These intervals are set and may vary by jurisdiction and cancer centre. Reliable reference intervals and standardized data elements and report formats for all laboratory tests help to improve clinicians' comprehension and use of test results.[55]

The laboratory report is the major communication link between laboratory medicine specialists/pathologists and clinicians.[55] Well-formatted reports that include complete content represent the best quality improvements that a laboratory can make.[56] Importantly, comprehensible information is needed to minimize errors, since it cannot be assumed that all clinicians will understand all the information included or its significance. Graphic displays of test results are especially important for reporting new proteomic and genetic tests. Various guidelines are available for the content of reports (e.g., Goldsmith et al.).[57]

Increasingly, reports are using a standardized or synoptic format, such as structured or discrete information (e.g., checklists). This format ensures that required data is reported and minimizes the use of free-flowing text, which is subject to interpretation and error. Synoptic reports improve communication between providers, especially across multiple sites, and can be used for other purposes, such as tumour registries, quality reporting, service planning and so on. The College of American Pathologists has developed cancer checklists – standardized and evidence-based protocols for the most commonly reported forms of cancer – which have been adopted as the content standard for pathology reporting in the United States and Canada.[58]

Centres must also establish a policy for the notification of critical values or results to the clinician. This includes identifying the diagnoses that they regard as urgent as well as giving examples of diagnoses that may be regarded as significant and unexpected.[59] For an example of safe practice recommendations for communicating critical test results, see Hanna et al.[60]

Finally, an important part of LMP reporting is the availability of a laboratory expert to answer anatomic and clinical pathology questions and discuss cases with the requesting clinician.

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13. PERFORMANCE MONITORING, REPORTING AND QUALITY IMPROVEMENT

As noted earlier, various international and national organizations have identified quality requirements and systems for laboratory medicine and pathology. These should inform the cancer centre's overall LMP quality performance effort, as well as directly influence quality activities within the LMP service.

Quality Framework

The cancer centre's LMP quality framework should include broad domains for performance improvement such as patient safety, staff satisfaction, and care that is timely, efficient, patient-centred, effective, accessible, equitable and appropriate.[61] These broad domains should align with the cancer centre's priorities and reflect the particular priorities of the LMP service. The selection of domains may also be influenced by international, national and subnational LMP standard-setting bodies, as well as by the external priorities of national or subnational health ministries or organisations that focus on quality in cancer care.

Examples of bodies that focus on quality in cancer care include:

- Agency for Healthcare Research and Quality[62]
- Canadian Partnership Against Cancer[63]
- Cancer Quality Council of Ontario[64]
- The National Quality Forum[64]
- European Partnership for Action Against Cancer[24]

Examples of LMP standard-setting bodies include:

- The International Organization for Standardization, which sets out management requirements for laboratory quality management systems and technical requirements for correct and reliable laboratory tests and calibrations[6]
- The Clinical and Laboratory Standards Institute, which sets out a quality management system approach that includes 12 quality system essentials basic to any organization[10]

A wide range of LMP staff should have input into selecting the domains.

Quality Performance Indicators

The cancer centre's LMP service should select quality performance indicators within each domain. As with domains, the selection of indicators should align with the cancer centre's priorities, reflect the priorities of the LMP service and may be influenced by the priorities of external bodies. A wide range of LMP staff should participate in selecting the indicators, and should have confidence in both the process used to select indicators and in the indicators themselves. Indicator definitions may be adopted or adapted from other reliable sources. Indicators must be clearly defined, measurable and reliable, incorporate the use of evidence or benchmarks, and be used to manage and improve the quality of the LMP service.

Generally, quality performance indicators should consider structures, processes and outcomes.[65] For the LMP service:

- Structures are the settings where services are provided and the related supports (e.g., LMP specimen collection, specimen receiving, specimen processing area, specimen analysis area, POCT areas, intraoperative pathology, storage, equipment, human resources, administrative structures, program operations and policies, etc.)
- Processes refers to the full range of LMP services the patient and requesting clinician receive, and how they are provided (e.g., appropriate, complete, technically competent, guideline-based, safe, co-ordinated, acceptable, etc.)
- Outcomes refer to complete and comprehensible test results and reports.

Other LMP performance indicators should be considered that go beyond structures, processes and outcomes, such as accessibility, timeliness of care, and the patient-centeredness of the service.[66]

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Numerous LMP performance indicators can be selected. The LMP service should select a manageable number of indicators to track. Table 4 presents illustrative examples of quality performance domains and indicators for LMP.

Table 4: Examples of Quality Performance Indicators for Laboratory Medicine and Pathology

Domains	Examples of Quality Performance Indicators
Accessible	• Wait time for LMP services within priority rating target • Equitable access to LMP expertise (i.e., internal and external requests) • Equitable access to tests (e.g., by age, gender, income, ethno-racial background, etc.) • Availability of LMP services to the population
Appropriate	• Use of priority rating scale • Appropriate number and mix of staff to meet LMP demands • Appropriate equipment and technologies to meet LMP demands
Effective	• Rate of pre-analytic errors (e.g., wrong test, wrong patient, wrong specimen, etc.) • Use of evidence-based LMP services • Number of second reviews • High-level team performance • Equipment functioning appropriately • Rate of downtime of the LIS • Achieve requirements of accreditation bodies
Efficient	• Turnaround times for all indicators in pre-analytic, analytic and post-analytic phases • Turnaround times for all tests • Turnaround times for overall pathology • Flow between pre-analytic, analytic and post-analytic phases • Total number of specimens • Total number of tests • Efficient use of laboratory resources (i.e., actual vs. budget) • Cost of supplies and clinical supplies per procedure
Patient-Centred	• Patient satisfaction levels • Patient complaints • Patient education and information
Safety	• Rate of false negative and false positive errors • Number of sample errors • Rate of disagreements between pathologists/diagnosis discrepancies • Percentage of pathologists' quality assurance reviews performed • Percentage of staff meeting continuing education and competency requirements • Number and severity of incidents in the laboratory • Near misses in the laboratory (e.g., unplanned event without injury, illness or damage, but with the potential for any or all of these adverse outcomes) • Sterility breaks
Staff Work Life	• Staff satisfaction • Staff absenteeism • Staff efficiency • Staff turnover • Overtime hours

Quality Infrastructure

A quality infrastructure with the following elements is needed to measure, monitor and improve LMP service performance.

First, information management support is needed to collect, analyze and report on indicators. The timing of indicator collection may vary from just-in-time to weekly, monthly, quarterly, semi-annually or annually. Regular access to LMP data and the ability to develop customized reports is critical to driving improvements. Customized performance reports may focus on discrete LMP phases, particular LMP activities, groups of medical and technical laboratory staff, or individual staff. It is best to provide performance feedback quickly and frequently, so that care and process improvements can be made.[66]

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Second, an LMP service quality team – made up of administrative leaders, medical and scientific leaders, managers, supervisors, quality experts (including the quality and safety manager, as required by ISO) and representatives of partner facilities, if appropriate – should assume overall accountability for quality and performance improvement. This team should review indicators in relation to evidence- and consensus-based benchmarks, and best practice standards and guidelines. The team should also engage staff to identify areas for improvement, establish improvement targets with associated timelines, develop action plans, support the implementation of change and track improvements.

Third, LMP service staff should receive ongoing training in quality improvement and patient safety, including best practices, adverse events (i.e., recognize, respond, report, disclose), and human factors. The latter includes factors that can influence people and their behaviour. In the cancer centre, these are environmental, organizational and job factors, and individual characteristics, which influence behaviour at work.[67]

Finally, to promote transparency and continuous quality improvement, performance information should be communicated to those working in the LMP service and, more broadly, to everyone in the cancer centre. Communications should include commentary on the data, expected plans of action and successes improving performance.

F. THE FUTURE

Advances in the field of laboratory medicine and pathology field are having a profound impact on the diagnosis and treatment of cancer. All advances have implications for the cancer centre's facility infrastructure and design, and equipment, human resource and training requirements. They also impact the role of laboratory medicine specialists/pathologists in various ways; for example, as LMP advances and moves towards personalized medicine, LMP staff will increasingly be required to change the way they work with other members of the healthcare team.

The traditional approach used in laboratory medicine and pathology is to take a tissue or fluid sample from a patient and physically transport it to a laboratory, where technicians process the specimen and prepare slides, laboratory experts examine the specimen with the naked eye or use microscopes, and LMP staff prepare and send a report back to the requesting clinician. Although the traditional approach continues to be appropriate in many instances, two major trends are influencing the evolution of laboratory medicine. These trends are presented separately below for clarity, but are closely interrelated.

Advanced Diagnostics Enabling Predictive Medicine

Increasingly, laboratory medicine specialists/pathologists are using advanced diagnostics to better characterize diseases and help predict and personalize the most effective cancer treatments for individual patients. Given that cancer is a change in cellular processes, advanced diagnostics take an in-depth look at the different aspects of cells. The most commonly used technique is molecular diagnostics, which analyzes biological markers in the genome and proteome by applying molecular biology to medical testing. Other advanced and sophisticated LMP diagnostics, which are being developed and hold promise for predictive medicine, include:

- Genomics, which studies the functions and structure of genomes or the complete set of DNA within a single cell.
- Proteomics, which studies the functions and structures of proteins, the main components of the physiological metabolic pathways of cells.
- Metabolomics, which studies the unique chemical markings or fingerprints that each cellular process leaves behind.
- Epigenomics, which studies modifications to the genetic material of a cell (i.e., epigenome) that are not caused by changes in the DNA.

As research continues to develop these diagnostic techniques – some of which may be more effective at providing predictive information than others – the demand on laboratory medicine and pathology to move research findings into the clinical setting will continue to increase.

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Innovative Technologies and Equipment

Laboratory medicine has, and will continue to, adopt innovative technologies and equipment to advance its ability to diagnose cancer. Major trends include the following.

Point-of-Care Testing

Increasingly, testing is occurring near the patient at the point-of-care rather than in a centralized laboratory. In the cancer centre, these tests may occur at the patient bedside, in an outpatient clinic or in a designated area near an operating room. POCT may also occur in the patient's home (e.g., diabetic patients checking their blood glucose levels).

POCT uses portable equipment and test kits, and provides test results almost immediately, which can then be used to make treatment decisions. The use of POCT for cancer diagnosis and follow-up is continuously being developed.

Rapid Diagnostics

The usual method of preparing and analyzing a specimen requires approximately 24 hours before a diagnosis can be provided. Patients who suspect they have cancer want their diagnosis as quickly as possible to minimize anxiety and allow treatment to begin.

Advances in new technology and the science of tissue fixation and processing are opening possibilities for rapid diagnostics. Increasingly, cancer centres are establishing clinics that use specialized equipment to fix and process tissue samples and provide a diagnosis within a few hours of a biopsy. The continuing challenge is a balance between the desire for a rapid diagnosis and the assurance of a scientifically accurate and reliable result. Given current scientific knowledge, there may be limits to how quickly an accurate and definitive cancer diagnosis and suggested treatment can be identified. Undoubtedly, this technology will improve over time and further evolve the role of laboratory medicine and pathology.

Increasing Automation

Laboratory medicine and pathology services in a cancer centre use automated systems to perform certain tasks, such as specimen handling and tracking. In addition, automated or semi-automated instrumentation is used to perform selected laboratory functions in such areas as hematology and chemistry. For example, automated systems provide a large percentage of high-volume, fluid-based test results, and computer software used in chemistry can help assess whether a sample has abnormal levels of constituents.[68]

The level of LMP automation will continue to increase as advanced instrumentation replaces manual tasks. Potential areas for automation include immunohistochemistry, transfusion medicine, cytology and molecular pathology. For example, computer software used in chemistry will be able to identify the presence of routine biomarkers such as the estrogen receptor and the progesterone receptor, as well as the Her2 status of a patient's breast cancer. Advanced software will also be able to provide laboratory medicine specialists/pathologists with current, evidence-based guidance on the impact and implications of multiple and complex test findings. Finally, as machine learning increases and becomes more sophisticated, pattern recognition, analysis and assessment may be performed by artificial intelligence.

The importance of initial and ongoing training to support automation and the use of advanced diagnostic techniques cannot be underestimated. This includes incorporating automation and advanced instruments into routine processing, and training staff to arrive at results and develop comprehensible and useful reports that support final diagnostic and treatment decisions.

Informatics

Informatics – which includes information systems and data processing and analysis – is expected to play an increasing role in LMP. Growth in the number of tests and the complexity of laboratory results due to advanced diagnostics will make it necessary to develop powerful information systems that can integrate massive data sets to support diagnostic interpretations.[68] This information may also be used for research

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and planning purposes. Appropriate physical infrastructure will be required to store the data in such a way that it can be mined to inform new testing or trends in the efficacy of treatment, mortality, etc.

It has been suggested that informatics and computational biology and their integration with hospital clinical systems may alter how diagnoses are made, leading to the development of "computational diagnostics" as a tool for clinical laboratories.[68]

Digitization to Enable Telepathology

Digitization in pathology is the process of preparing digital images of pathology specimens (i.e., tissues on glass slides). Digitization enables telepathology, which is the electronic sharing of digital images to obtain a pathology diagnosis from trained pathologists. Images can be shared within the cancer centre (e.g., digital images viewed in regular multidisciplinary cancer conferences/tumour rounds), and between the cancer centre and other hospitals. Digitization can be used for dynamic or real-time pathology services, where pathologists at the cancer centre view real-time digital images and are linked with surgeons at other hospitals during intraoperative biopsies. Digitization can also be used to support rapid diagnostic clinics across a geographic area.

Digitization is revolutionizing access to pathology interpretations, which were previously limited or constrained by geography. Digitization reduces delays by eliminating the need to transport specimens physically, which can take hours or days depending on the distances and increase the possibility of lost or compromised specimens. Digitization also eliminates the need for patients to travel long distances to the cancer centre for biopsies and, thereby, removes barriers to care for patients living in remote areas.[69] Furthermore, digitization increases access to expert pathology opinions, since subspecialty pathologists tend to be located in larger cancer centres. This access is expected to improve diagnostic accuracy, as more cases are viewed by the most appropriate specialist pathologist.[70] Digitization may also improve economies of scale and productivity, since pathologists may be able to process more cases with greater administrative efficiency.[70]

Telepathology has been successfully piloted in many high-income countries that service remote areas with small populations, such as Canada, Australia, United States and Japan.[71]

Facility requirements to support digitization go beyond the cancer centre. Requirements include high-speed scanners to produce high-quality digital images at the sending site, high-frequency electronic networks to transmit digital images between the sending site and receiving cancer centres, and advanced computers at the receiving cancer centre to view and interpret the digital images. While digital pathology requires a significant upfront investment, it may save money and free up resources to be reinvested in other areas over the long term.

G. SUGGESTED READING

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