Review Article

Pathological and Radiological Correlation of Diseases in Contemporary Medical Practice

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ABSTRACT

In modern times clinical care of patients relies heavily on the specialties of radiology and pathology for diagnosis. The two specialties have always existed independently in medical institutions, with some level of cooperation when there is the need to correlate the findings in specific patients; in recent times, particularly in breast cancer screening and diagnosis, bone pathology and image-guided biopsy.

Pathology and radiology have had different historical and developmental experiences, but both have seen an explosion of knowledge, and technological, and scientific developments in recent times. Rudolf Virchow (1821-1902) is considered as the father of modern pathology, while Wilhelm Conrad Rontgen is the discoverer of electromagnetic radiation the basis of X-ray. The field of histopathology has made tremendous progress, particularly in the area of immunohistochemistry and the application of molecular techniques, which are useful in the diagnosis and follow up of cancer patients. These form an important basis of personalised medicine. Modern radiology relies on mammography, ultrasound, computerised tomography, magnetic resonance imaging, positron emission tomography, nuclear medicine and interventional radiology.

Pathology and radiology form the core of cancer diagnosis in clinical practice. Specific areas of cooperation between the two fields include fine needle aspiration cytology, breast cancer control programme, sentinel lymph node localization, cases of adenocarcinoma of the lung with specific signatures, and interstitial lung disease.

Finally, standardization of reports will ensure use of controlled terminology and reporting structures. There is need to commence radiologic pathologic correlation courses for residents in the country as is practiced in the North America in order to partly meet this challenge.

Key Word: Pathology; Radiology; Correlation; Personalised medicine; Cancer management; and Immunohistochemistry.

INTRODUCTION

In centuries BC Egyptians, Greeks and Romans were investigating diseases in their own way. In medieval Europe, early Christians believed that disease was either direct punishment for sin or the result of witchcraft. Diagnosis was not necessary and the basic therapy was prayer, penitence and calling on saints for help. The first diagnoses were made by early physicians using their eyes and ears, and sometimes the study of urine.

In modern times clinical care of patients relies heavily on the specialties of radiology and pathology for diagnosis. To a large extent also for screening purposes, some level of prevention, prognosis, and follow up, particularly in cancer patients. The two specialties have always existed independently in medical institutions, with some level of cooperation when there is the need to correlate the findings in specific patients; in recent times, particularly in breast cancer screening and diagnosis, bone pathology and image-guided biopsy. Pathology and radiology have had different historical and developmental experiences, but both have seen an explosion of knowledge, and technological, and scientific developments in recent times. We are called upon by clinicians to make presentations in clinico-pathological meetings or in tumour boards. Hitherto, we do not usually consult each other frequently in clinical matters, until in the last 20 to 30 years, with the advent of image guided biopsy and now personalised medicine, which had brought us even closer. This closeness has allowed us to appreciate how interrelated our work is and the potential of making our specialties more relevant in the clinical management of patients. In developed parts of the world, in North America and Europe they are beginning to talk about the integration of radiology and pathology reports, without the loss of independence by either specialty.

In Nigeria, our two fields have been able to gain the respect and admiration of our colleagues in other specialties in view of the contributions that we make to the practice of medical profession and training. The two postgraduate medical colleges (National Postgraduate Medical College of Nigeria - NPMCN and the West African Postgraduate Medical College - WAPMC) have contributed significantly to these specialties in terms of training and accreditation. Records from NPMCN show that it has produced 200 and 67 fellows in pathology and radiology in the last seven years respectively.[1]This is very commendable as it ensures that our tertiary medical facilities, and undergraduate and postgraduate educational programmes are sustained in these two medical fields.

HISTORY AND DEVELOPMENTS IN MODERN PATHOLOGY

In the eighteenth century, science was held in high esteem and physicians upgraded their social standing by becoming more scientific. One of the most important events in medical history was the discovery of blood circulation by **Williams Harvey (1578-1637)**, which marked the beginning of a period of mechanical explanation for digestion, metabolism, respiration and pregnancy.

The first recorded work in pathology can be credited to the Italian physician **Antonio Benivieni (1443-1502)**, who wrote down case histories and performed autopsies on some of his patients.[2]

The invention of the microscope, which is credited to **Antonie van Leeuwenhoek,** opened the door to the invisible world. Later in the nineteenth century, many scientists were able to make great strides in bacteriology, microbiology and histology based on this instrument. Improvements in the microscope allowed further exploration of the cellular and microbial world.[3]

Rudolf Virchow (1821-1902)[4] is considered as the father of modern pathology. He was a **physician, anthropologist, prehistorian, biologist, writer, editor and politician**. His scientific writings exceeded 2,000! His book –**"Cellular Pathology"** published in 1858 is considered as the root of modern pathology. He was the first to precisely describe and give names to diseases like **leukaemia, chordoma, embolism, thrombosis, and ochronosis. He coined the following terms – chromatin, agenesis, parenchyma, amyloid degeneration, osteoid, and spina bifida,** all of which we still use today. A number of scientific terms had been named after him – **Virchow's Triad, Virchow-Robin spaces, Virchow's node and Virchow-Seckel syndrome**. He was the first to use hair analysis in criminal investigations. He also founded one of the most respected pathology journals, that is still published today -Archiv für pathologische Anatomie, Physiologie und für klinische Medizin now called **Virchows Achiv**.

Rudolf Virchow (1821-1902)
(Source – Wikipedia)

In modern times the broader field of pathology or laboratory medicine can be divided into four mainsubspecialties:

Histopathology and morbid anatomy

Haematology and blood transfusion
Medical microbiology
Chemical pathology

Other areas of pathology[5]
Oral pathology
Genetics and reproductive science
Immunology
Toxicology
Virology
Neuropathology
Prenatal, perinatal, and paediatric pathology
Histocompatibility and immunogenetics

When the term pathology is used without any further qualification, it is usually meant to refer to the subspecialty of histopathology and morbid anatomy (anatomical pathology). The remaining three main subspecialties mentioned above are sometimes referred to as **Clinical Pathology** due to the nature of their practice. In this presentation we are mainly concerned with histopathology and morbid anatomy or anatomic pathology, but we may make reference to the other subspecialties in general way.

Pathology as a Field of General Inquiry and Research Addresses Four Components of Disease:
Aetiology or cause
Pathogenesis or mechanism of disease
Morphological changes or structural alterations
Clinical manifestations.

Branches of Anatomic Pathology:
Morbid anatomy
Histopathology
Cytopathology
Forensic pathology
Surgical pathology
Molecular pathology

Some Techniques Used in Histopathology
Routine stain (Haematoxylin-Eosin stain)
Cytology
Fine needle aspiration cytology (FNAC)
Special stains (histochemistry)
Enzyme histochemistry
Tissue culture
Histometry (quantitative methods)
X-ray microanalysis
Electron microscopy
Immunohistochemistry
Flow cytometry
Cytogenetics
Molecular biology/pathology techniques

Molecular Biology Techniques
Tissue microdissection methods
Filter hybridization (Southern, Western& Northern blotting techniques)
Amplification methods (PCR)
Gel electrophoresis method
Hybridization methods (ISH, FISH methods)
Interphase cytogenetics
Nucleic acid sequencing
DNA microarrays (not to be confused with tissue microarray technique)

Implications of Molecular Pathology and Personalized Treatment to the Practice of Pathology[6]
Immunohistochemistry is the forerunner of modern molecular diagnosis and it brought a revolution in diagnostic accuracy and disease investigation to histopathology practice. **Molecular methods** are the new frontiers in this regard. Immunohistochemistry itself grew from **Histochemistry**.

The application of molecular pathology and modern genetics may appear to be a threat to the future existence of the pathologist. The field of pathology has not seen such rapid changes since the time of Rudolph Virchow, the father of modern pathology. Although one is comforted by the fact that despite advances in the molecular make up and genetics of cells, histopathological examination of tissue is still the first and essential step in making tissue diagnosis, this will always ensure the relevance of the pathologist in the clinical management of patients.

Digital imaging systems are now replacing microscopes in histopathology in the developed countries, and this is opening up the possibility that image analysis will enter routine clinical practice for the measurement of tumour size, grade and protein expression.

The clinical role of the pathologist now goes far beyond making a diagnosis, as we are increasingly involved in decisions on treatment, and monitoring of response to treatment. An understanding of the aetiology and pathogenesis by the pathologists must therefore be matched by an understanding of what treatment will do at every level – molecular, cellular, whole organism and the whole person.

Sequencing technology is another new and advancing field in pathology. This technique processes a large amount of data, which is a challenge to interpret and report. This method is likely to be used by all the main branches of pathology, for example **Whole Genome Sequencing (WGS)**,perhaps applied at birth may one day replace neonatal screening, thus providing lifelong pharmacogenetic information and allow risk-based disease screening.[6]

The new and advanced techniques mentioned above are all technological advances, which show no sign of slowing, only acceleration. This is changing the face of pathology and we fear if we will lose our positions to other professionals in future. But, this appears not to be so, as no specialty of pathology has disappeared, and we all continue to work side by side with other scientists, biochemists, immunologists, serologists, etc, in this new environment without any one losing their identity. In the future, pathologists may be known by clinical colleagues more for their interpretation and reporting of results than their work in the laboratory.

Personalised Treatment

We need to **PersonaliseTreatment (a.k.a personalised medicine, stratified medicine,& precision medicine)** because we are all different. We differ genetically, the bacteria and viruses that infect us differ, our lifestyles differ and the environments in which we live differ. These differences mean that we respond differently to treatments for disease. For instance, analysisof the individual'scancer cells using other cells, protein, RNA and DNA allows us to predict their behaviour in response to particular treatments. For many cancers personalised therapy based on laboratory diagnosis is now routine practice and is producing amazing results. We now have the ability to tailor treatment to individuals, with targeted drugs and companion diagnostic tests. The pathologist is playing an important and central role in this new form of therapy.

The methods used to provide personalised medicine are evolving rapidly. There are now many DNA sequencing and other methods available. The choice of which one to use depends on many factors, particularly the diagnostic information required and when it is required. Timely diagnosis is essential for many patients, and should influence when and where tests are performed. There is evidence to support **"liquid biopsy"** of cancers using circulating cells, nucleic acid and proteins for diagnosis, and to monitor the efficacy of treatment.[6]

One of the effects of personalised medicines is that many patients will live longer, but sadly many will eventually succumb to their cancers. This will have cost implications, as many rounds of treatments may be necessary. There is need for an improved scientific understanding of diseases by the pathologist as the complexity of care increases with a matching demand on diagnostics, which are expected to prove the scientific evidence necessary to optimise treatment. Medical imaging will have to provide its share in this regard, although the investigation of most molecules and cells requires a laboratory.

Departments of pathology would have to change in order to cope with anticipated changes in the scope and depth of medical care. Some of the areas of changes include the following:

Automation
Clinical translation
Computing and information technology
Immunohistochemistry
Digital pathology and image analysis

HISTORY AND DEVELOPMENTS IN MODERN RADIOLOGY[7,8]

The origin of radiology began with **Wilhelm Conrad Röntgen**, a German mechanical engineer and physicist who was the first person to produce and detect electro magneticradiation in a wavelengthrange, known as **X-rays or Röntgen rays** on 8th November 1895. This earned him the honour of the **first Nobel Prize in Physics** in 1901, and his name being given to the**111th element of the Periodic Table - roentgenium (Rg)** a radioactive element with many unstable isotopes, by the **International Union of Pure and Applied Chemistry** in 2004.Although Röntgen's hand was the first human part to be X-rayed, the first patient to be X-rayed was his wife, her left hand including her wedding ring. Significantly, Röntgen donated the proceeds of his Nobel Prize to his university, and refused to take out a patent for his discovery of X-rays, as he wanted mankind as a whole to benefit from its practical application.

The public was fascinated by this discovery (X-rays), and all sorts of persons wanted to take advantage of it, including photographers and detectives who wanted to use it to detect unfaithful spouses! However, the medical world immediately recognised the enormous importance of such a discovery, and began to take advantage of it. In January 1896, less than a year after Röntgen's discovery, Emil Grubb, an American electrotherapist irradiated two cancer patients with X-rays and noted palliation. He himself had to have over 100 operations, including amputations later in his life due to lifelong exposure to X-rays.[7]

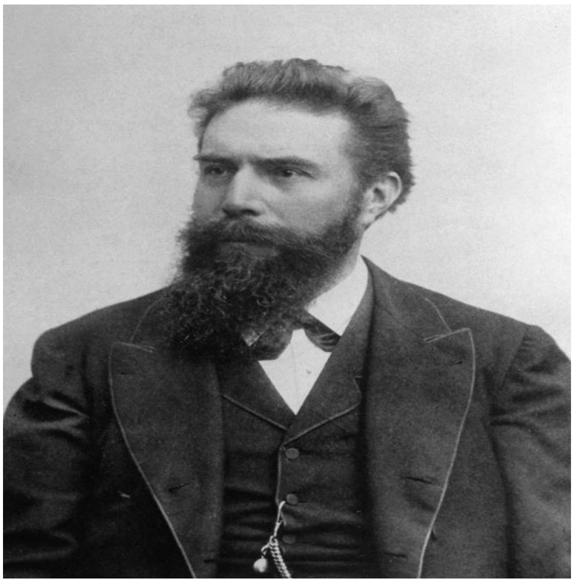

Fig2. Wilhelm Conrad Röntgen(1845-1923)
(Source – Wikipedia)

Fig.3 Left hand of Röntgen's wife, the 1st X-ray ever taken (Source – Wikipedia)

X-ray is the basis of what radiologists call the **"plain film"**, used commonly to evaluate the chest and bone fractures. The original X-ray film had to go through a developer process in the dark room. Sometimes, due to urgency, a "wet film"would be reported while still dripping, a nametag still used for an emergency radiology report even though most films are now digitally produced. This early practice continued for the next 20 years until the advent of **fluoroscopy**, as the X-raybeams become powerful, and patient motion can be visualized, by giving patients radio-opaque barium as a swallow or rectally. This was how cancers of the oesophagus, stomach, and the bowel, as well as ulcers, diverticulitis, and appendicitis were initially diagnosed by radiologists. Fluoroscopy is still in use today, albeit with more powerful machines.

Mammography

Mammography is also based on X-rays, when high-resolution images of breasts are taken in search of early breast cancer. Over the years, the X-ray dosage used has reduced considerably making the process safer. Now such films are digitally produced directly from high-resolution workstations.

Angiography

X-ray is the basis of **angiography** or the imaging of blood vessels. This technique came in the 1950s, initially a radiodense contrast like iodine was injected directly into the artery of interest, as in an area of suspected stroke, vascular malformation or tumour. A flexible guide wire is inserted through the puncture needle and a plastic guide wire is run through the blood vessels to the organ. The contrast agent is then injected, as this will enable a diagnosis to be made, for example narrowing of the carotid or coronary arteries, which could lead to a stroke or myocardial infarction respectively.

Interventional radiologists and cardiologists routinely expand narrowed vessels with a balloon ("balloon angioplasty") often followed by a coil of wire called a "stent" in order to keep the vessel open after the procedure.

Nuclear Medicine

Nuclear medicine entered the arena of diagnostic imaging tests in the 1950s, it is also based on X-rays, except here the source of the X-rays is a radioactive compound rather than an X-ray tube. These compounds emit gamma rays as they decay; they are combined with other compounds that are taken up as part of the disease process. For example, Technetium 99m can be combined with methylene diphosphonate, which is then taken up by bone being invaded by a tumour. In this case, when cancer of the breast has metastasized to the bone, it can easily be detected by such a nuclear bone scan.

Positron Emission Tomography (PET)

Positron Emission Tomography (PET) is a branch of nuclear medicine based on positron-emitting isotope of **fluorine (F-18)**that is incorporated into a glucose analog called **fluorodeoxyglucose (FDG)**. Since most cancers have an increased uptake of glucose, the **FDG PET** has become a mainstream technique to diagnose both primary and metastatic diseases. The FDG PET can be combined with CT, with its high resolution, in order to facilitate localization of cancer for biopsy, radiation therapy, or surgery.

Ultrasound

The Ultrasound technique was first used clinically in the 1970s; it uses sound waves instead of ionizing radiation. As sound waves pass through the tissue and are reflectedback, tomographic images can be created and tissues can be characterized. For example, a mass found ina mammogram can further be characterized as solid (possibly cancer) or cystic (most likely benign).

Ultrasound is useful in the noninvasive imaging of the abdomen and pelvis, including during pregnancy. Early machines were bulky with articulated arms that produced low-resolution images. Today ultrasound can be performed using portable units, not larger than a laptop.

Computers in Radiology

Computers entered the world of imaging in the early 1970s with the advent of **Computed Tomography (CT scanning**) and later **Magnetic Resonance Imaging (MRI)**. CT was a major advance that first allowed multiple tomographic images (slices) of the brain to be acquired, before this time only plane X-ray films of head can be made. These show only bones, or in the case of angiography, only suggest masses when vessels of the brain are displaced from their normal positions. Before the advent of CT and MRI there was no way to directly image the brain.

In CT an X-ray tube rotates around the patient and various detectors pick up the X-rays that are not absorbed, reflected, or refracted as they pass through the body. Early CT units produced crude images on a 64X64 matrix and early computers took all night to process these images. Today's multidetector row CTs acquires multiple submillimeter spatial resolution slices with processing speeds in milliseconds rather than hours. Iodine contrast agents are usedwith CT since they block X-rays based on their density compared with that of normal tissue.

Magnetic Resonance Imaging (MRI)

The MRI evolved in the 1970s also, being based on resistive magnets with weak magnetic fields, which produce images with low spatial resolution. These gave them a better soft tissue resolution compared to CT, making an earlier diagnosis in disease process possible. MRI also had the advantage of not using the ionizing radiation compared to the X-ray based CT. Between 1980s and 1990s, superconducting magnets became common, initially at 1.5 Tesla and now 3 Tesla. (Tesla is a measure of magnetic field strength. The earth's magnetic field is .00005 Tesla for comparison).

Most clinical MRIs are based on hydrogen ion, with its single proton, which resonates at frequencies in the radiofrequency range. When a proton resonates it can be detected by a radio antenna, in the form of a coil stationed around the body part being imaged. The precise mechanisms used in MRI are based on complex chemical and physical properties of protons as they resonate under different environmental conditions**(Nuclear Magnetic Resonance "NMR")**. By varying the magnetic field (e.g. 10x), andsuppressing water over a small region of the brain different chemical species can be detected as they resonate differently **(MR Spectroscopy or "MRS")**. This mechanism provides the ability to perform chemical analysis of the brain noninvasively.

A technique known as **Functional MRI (fMRI)** allows parts of the brain, with the patient still awake to be studied, such thatvarious types of strokes in the CNS can be studied with important implications on their management. This richness of contrast mechanisms is one of the primary advantages of MRI over CT.

Gadolinium contrast enhancement is the counterpart of iodinated contrasts in CT, which allows the performance of perfusion imaging of the brain. This is able to provide a measure of cerebral blood flow, mean transit time, and cerebral blood volume. This is a less invasive study of cerebral, coronary and other blood vessels in the body through **contrast-enhanced venous MRI angiography** compared to the**catheter-based arterial angiography**.

MRI is also useful in the evaluation of the heart, and the diagnoses and treatments of prostate and breast cancers. The procedure is also useful in monitoring certain treatments in real time. In the operating room it also allows the neurosurgeons to ensure that the entire brain tumour that can be safely removed has been removed.

Computed Tomography (CT) in the Emergency Room Using modern multidetector CT scanners (CT angiography - CTA), patients presenting in the emergency room with acute chest pain are better managed compared to the need to take them to a cardiac catheterization laboratory in order to do femoral arterial catheterization. Such that only those patients with coronary occlusions need to be taken to such a laboratory for angioplasty or and stenting.

In developed countries, a multidetector CT is frequently the first test ordered in such patients, with a scan covering the entire body that can be performed in 20 seconds. This allows for a fast screening of bony fractures, lacerations of the liver or spleen or the evaluation of patients with stroke in the emergency room.[8]

Vascular and Interventional Radiology (VIR)

Vascular and Interventional Radiology refers to a range of techniques which rely on the use of radiological image guidance to precisely target therapy. The techniques these specialist radiologists use are X-ray fluoroscopy, ultrasound, computed tomography, or magnetic resonance imaging. The interventional radiologist has the skill and training in diagnostic image interpretation and the manipulation of needles and the use of fine catheter tubes and wires to navigate around the body under image control. There is hardly any area of patient care that IR has not had some impact.

The range of conditions IR treat are varied and include:

Vascular diseases like stenosis, aneurysms, haemorrhage, pulmonary embolism, varicose veins, venous thrombosis (DVT) etc.

Non - vascular interventions like tumour embolization/ablation, tumour therapies (ablation, heat method – laser, radiofrequency, microwave or ultrasound, cryotherapy); delivering chemotherapeutic agents to primary or metastatic sites;embolization of fibroids; kidney or gall stones, etc.[9]

RADIOLOGY-PATHOLOGY CORRELATION/INTEGRATION

Pathology and radiology form the core of cancer diagnosis in clinical practice. However, as mentioned earlier they are distinct units with little interaction.

The radiologist has provided clinicians with increasingly sophisticated noninvasive visual representations of disease. This is more apparent in the evaluation of cancer, where imaging is used in almost all facets of the disease. The primary value of medical imaging is the information that imaging provides with respect to the underlying pathology being viewed. The bedrock of radiology has been radiologic-pathologic correlation, i.e. the correlation of imaging to ex vivo gross and histopathologic findings of disease. The relationship between radiology and pathology has persisted essentially unchanged in form to this day.

Dr Lauren V. Ackerman (1905-1993), one of the greatest pathologists in modern times wrote as foreword in the earlier edition of his book on surgical pathology:
"… a department of pathology in a large medical center should have a division of surgical pathology closely affiliated with clinical and surgical departments. Surgical pathology implies surgery, but the modern surgical pathologist is closely affiliated with many branches of medicine. This includes all the surgical specialties, internal medicine, dermatology, neurology, diagnostic radiology, radiation therapy, and medical oncology. Although the study of radiology deals with shadows and the study of pathology with substance, the correlation of those shadows with gross substance strengthens the diagnostic skills of the radiologist, explains errors in radiologic interpretation, and instills humility rather than dogmatism. The radiotherapist andmedical oncologist, too can learn much from the study of surgical pathology, particularly the correlation between sensitivity to therapy and microscopic tumour types and the effects of therapy on normal tissue…."[10]

In the developed countries steps have been taken to bring the two fields of radiology and pathology closer. The advent of breast cancer screening using mammography and image guided tissue biopsy had further brought the two specialties together. However, currently, the most important incentive for correlation of the two specialties is the recent developments in the management of cancer patients using personalised medicine, through the application of genomics and molecular medicine.

The traditional areas of cooperation between radiology and pathology are in image-guided biopsies and breast cancer screening.

Image Guided Biopsies

Image guided biopsies can be obtained by the radiologist or in case of FNAC sometimes by the pathologist using an appropriate biopsy needle under the guide of X-ray, mammography, ultrasound, computed tomography, MRI-guided or stereotactic. The biopsy can be needle aspiration or a core biopsy, when a thin core of the tissue is obtained. Nearly any tissue in the body can be targeted, but the common ones are thyroid, liver, kidney, breast, prostate, bone, lymph node, lung or a cyst.

Breast Cancer Screening

Breast cancer screening using mammography is a low-dose X-ray examination of a woman's breasts in order to detect cancer when in its early stages before it is palpable. Screening is carried out on women who are symptomless of breast disease, with the aim of reducing death rate from breast cancer by detecting unsuspecting breast cancer at an early stage. In developed countries free mammographic examinations are carried on all women between the ages of 45-69 years. Surgeons, radiologists and pathologists cooperate closely in such programs.[11]

On the need for integration of radiology and pathology reports

James Solace and his colleagues have advocated a position on the need for the integration of pathology and radiology reports in certain situations. They argued that data generated by radiologists and pathologists are essential to making correct diagnosis, appropriate patient management and treatment decisions; further noting that the isolation of radiology and pathology workflows is detrimental to the quality and outcomes of patient care. With enormous technological advances currently occurring in both fields, the opportunity has emerged to develop an integrated reporting system that supports both specialties and therefore, improves the overall quality of patient care.[12]

They identified the following areas of such integration:

Disease-specific areas in diagnostic medicine

Several studies have shown that the integration of mammography and pathology reports in breast cancer diagnosis detects misdiagnosis, allowing a prompt repeat biopsy in instances of unexplained discrepancy between imaging and pathologic findings.

Cases of sentinel lymphnode localization, when targeted lesions and resection margins must be localized and mapped in order to determine the adequacy of resection. This kind of cooperation can both prevent the need for re-excision and improve the reporting of survival related prognostic factors.

Cases of lung cancer where an integrated, multidisciplinary approach is required for optimal patient care, in order to take advantage of the recent discovery of specific molecular signatures in adenocarcinoma, which responds to specific targeted therapy. Additionally, a lesion characterized by high-resolution helical CT has introduced a new classification of peripheral lung lesions that correlate well with histologic features and therapy.

Similar benefits are observed in patients with interstitial lung disease, who historically belong to the domain of pulmonologist, who would get reports independently from radiologists and pathologists. There is an international consensus now that an integrated and dynamic interaction among the three specialties could identify subsets with specific biologic factors that could influence prognosis.

Pathology-radiology integrationmay improve the classification and diagnosis of somevascular tumours.

I want to observe that the repotting of bone/skeletal neoplasms is another major area where sufficient integration is being achieved. The pathologist is required to be fully aware of, among other parameters, the radiologic appearance of tumours of the skeletal system before making the evaluation of their microscopic appearances. The **WHO Working Group on Soft Tissues and Bone** also recommends combining both radiological and histological criteria in their diagnoses.

Other General Benefits of Pathology-Radiology Integration

Other than the documented benefits to patient management mentioned above, other potential areas of such a relationship include among others:

Report standardization would encourage the use of controlled terminologies and standardized reporting structures, making evaluation across multiple cohorts possible.

Clinical efficiency would benefit from having a single portal of reporting, which could free more time for interpretation and decision-making.

Registry development. The aggregation of diagnosticimaging and pathologic data into a single resource would facilitate the development of rich databases.

Tumour presentation. Such integration would lessen preparation time for multidisciplinary tumour board meetings, and would be a valuable educational resource for medical students and residents.

Research and innovations. Recent advances in both radiology and pathology are encouraging closer cooperation between the two fields, especially as tumours are now being identified at an earlier stage than previously, and are being characterised at molecular level. A rapid access to comprehensive pathology and radiology findings will be necessary to enable novel translational research activities.

Improved patient care. In addition to the benefits noted above, greater coordination would encourage the use of less invasive techniques, while at the same time ensure that adequate material is available for additional studies, including molecular studies.

FINAL THOUGHTS ON THE TWO SPECIALTIES OF PATHOLOGY AND RADIOLOGY

The departments of pathology and radiology are the backbone in the diagnosis of cancer, arguably the most important disease that physicians treat in the modern hospital setting. From above we have seen the potential benefits of close cooperation between the two specialties. In daily hospital practice and in the course of training of specialists into these professions, there is little formal interaction except in clinicopathological meetings. Although radiology and pathology each independently receive trainees from other clinical areas during their training periods, we do not send our trainees to learn from each other in a routine and formal way.

All images generated by radiologists are related to pathology in the tissues and organs of the body. One can therefore safely say that there is no radiology without pathology. In North America and Europe, recognition of this has led to the creation of academic programs to address the need for radiologists to have knowledge of pathology beyond that acquired in medical schools. **The Armed Forces Institute of Pathology (AFIP)**, one of the most world-renowned institutes of pathology had Department of Radiologic Pathology since 1944 (during the 2nd World War). This department had been offering **Radiologic Pathologic Correlation Courses** with the strong support of the radiology and pathology community in the USA and Canada, such that nearly 90% of all radiology residents in the USA and Canada, and from all the over the world, attend such course during their training.[13] This department of AFIP has now transformed in 2011 into the **America Institute of Radiologic Pathology**, as an arm of the **American College of Radiology**, and continues to offer the correlation course as a 6-week program.[13]I am not aware if any of the Faculties of Radiology of either of our postgraduate medical colleges in the country is offering any such courses. If not, then, it may be time to consider the idea of doing so.

Internal and External Threats to our Specialties in Nigeria Today

Another issue of great concern to me (and others as well) is the existing or potential threats to our professions i.e. pathology and radiology, and possibly, other medical specialties in the country today. One is internal, the other one external. The internal one is lesser of the two but must also be taken seriously. It is the inter-professional squabbles between pathologists and laboratory scientists on one hand, and radiologists and radiographers on the other. Hitherto, we have worked hand-in-hand happily for the good of our patients and professions. But in recent years we feel that our positions as the leader of the health team, and as senior partner in the relationship is being challenged. On the other hand our junior partners feel that we are not serving their best interests, or are not interested in their professional progress. This situation is most unfortunate and must be arrested before it does our professions more harm. I feel that the onus is on us the senior partner in the relationship to once again gain the confidence of partners. We must establish lines of communication and dialogue with our colleagues with the view of understanding one another.

The external threat is more serious in my view. It borders on our continued relevance in the health care team. We are important mainly because our clinical colleagues cannot treat patients effectively without getting our input in terms of diagnosis, monitoring of therapy and follow up. In the laboratory, the modern era of personalised medicine demands that we use molecular techniques, the setting up of which requires huge investment in terms of manpower, equipment and reagents. On the other hand, radiologists need very expensive equipment, with commensurate running costs and maintenance. Machines like CT Scanners, MRI, ultrasound etc easily costs hundreds of millions of naira. The question is how do our institutions acquire such costly items? It is very clear that government cannot provide such funds from its coffers. Do we turn to the private sector in the form of **Public-Private-Partnership (PPP)**? Or do we tap the good will of rich Nigerians? We must find a way out.

An issue closely related to above is our output in our various institutions. The situation in most public tertiary hospitals where most of us practice is that you find sometimes up to 5 or more consultants in a department where the annual output justifies the employment of only one consultant. How do we solve this issue? For the sake of our conscience, and the future of our jobs we must find a way to address this. One only needs to look at the situation at the secondary level of care i.e. our state general hospitals to see that there is a lot of work to be done, while there are virtually no specialists to do the work at that level of care. We must find ways in which to redistribute the manpower now concentrated at the tertiary level of care in the country. This applies to nearly all the various types of medical specialties.

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REFERENCES

1. Source - NPMCN, August 2017.
2. den Tweel JG, Taylor CR. A Brief History of Pathology. Virchows Arch. 2010; 457(1): 3-10.
3. History of Pathology. Northampton General Hospital, NHS Trust. www.northampton.nhs.uk accessed on 27th August 2017.
4. Wikipedia accessed on 29th August 2017 at 3.14pm.
5. Royal College of Pathologists. www.rcpath.org accessed 27th August 2017.
6. Cree I. Overview of Molecular Pathology. Bulletin January 2016. Number 173. www.rcpath.org.
7. van Gelderen F. Understanding X-rays. A Brief History of Radiology. Springer-Verlag, Berlin Heidelberg. 2004.
8. Pp.597-602.
9. Bradley WG. History of Medical Imaging. Proceedings of the American Philosophical Society 2008; Vol. 152, No. 3: 349-361.
10. Kessel D. What is Interventional Radiology? British Society of Interventional Therapy. www.bsit.org accessed on 28th August 2017 at 2.36pm.
11. Rosai and Ackerman's Surgical Pathology. Introduction. 10th ed. Elsevier 2011. Pp.1-24.
12. WHO position paper on mammography screening. WHO. 2014.
13. Sorace J, Aberle DR, Elimam D, et al. Integrating pathology and radiology disciplines: an emerging opportunity? BMC Medicine 2012, 10:100. Available at www.biomedcentral.com/1741-7015/10/100 accessed on 28th August, 1.50pm.
14. Murphy MD, Madewell JE, et al. A history of Radiologic Pathology Correlation at the Armed Forces Institute of Pathology and its Evolution into the American Institute of Radiologic Pathology. Radiology 2012, Vol262;2. http://doi.org/10.1148.11111357 accessed on 29th August 2017.