In the outpatient setting, it has been shown that greater stress from uncertainty and too high perceived workload are associated with higher levels of general practitioner burnout. The use of consultation has been shown to be inversely related to workload intensity, and, thus, primary care physician stress. Similarly, consultation in the inpatient setting has been shown to be an essential tool for accurate and timely diagnosis; in fact, its use can be an indicator of patient complexity.

Why Do We Need Nuclear Medicine Consultation?

Nuclear medicine is a clinical and laboratory medical specialty that uses radioactive tracers to study physiologic, biochemical and cellular processes for diagnosis and therapy. As a physiologic imaging modality gathering of information pertaining to all aspects of the patient including history, physical examination, and diagnostic testing prior to, and at the time of, imaging is requisite to methodology selection and image interpretation. Careful consideration of all relevant clinical information has been shown to have major influences on interpretation of nuclear imaging, and can vastly improve specificity. Although impact on patient management has not been studied extensively – in both the inpatient and outpatient settings, formal consultation allows the nuclear medicine clinician to formally and completely evaluate the patient, choose the most appropriate molecular imaging technique to assess the particular physiologic process in question, and give a more definitive diagnosis on the basis of imaging findings. Formal nuclear medicine consultation can aid in accurate diagnosis.

Molecular Tracer Selection for Localizing Infection

For instance, the algorithmic approach in diagnosing infection through the various molecular imaging techniques has been well described. However, there should be knowledge of available techniques.

Keywords: Consultation, molecular imaging, nuclear medicine, referral, subspecialty

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Local equipment, personnel, and radiopharmaceuticals in a particular clinical setting.[7] Choosing an alternatively appropriate study in scenarios where the desired nuclear medicine study cannot be performed, due to lack of any one of the above-mentioned indispensable components, may require the expertise of a nuclear medicine specialist. For example, if the local radiopharmacy is not equipped to radiolabel leukocytes for infection imaging, then a decision must be made whether to pursue alternative methods including $^{18}$F-FDG PET or $^{67}$Ga-Citrate SPECT imaging, based on availability and whether the patient can undergo a multi-day study or not. Similarly, in patients with fever of unknown origin, although radiolabeled leukocyte scans utilizing $^{111}$In-oxine or $^{99}$mTc-HMPAO labelled leukocytes would be desirable, this may not be feasible in the case of leukopenic patients.[6]

Furthermore, imaging characteristics for each radiopharmaceutical and labelling technique must be carefully considered for each patient.[8] Clinicians inexperienced in nuclear medicine are privy potential pitfalls in imaging for each molecular imaging technique used in diagnosing infection.[7] For instance, in a patient being worked up for vertebral osteomyelitis $^{67}$Ga-Citrate may be desirable, but if the patient received gadolinium contrast for a contrast-enhanced MRI, then the bio-distribution of the tracer would be significantly altered.[9]

In multi-day studies, including $^{111}$In-oxine labelled leucocyte and $^{67}$Ga-Citrate studies, there can be a drastic effect on the length of stay, if an incorrect or inappropriate study is requested. A nuclear medicine specialist can readily determine, after formal evaluation, or chart review, the appropriate patient preparation required and even whether a nuclear study is appropriate. Although validation is needed, this could not only decrease length of stay, if the imaging study is not warranted, but it can also improve diagnostic accuracy because of better patient preparation. This could be examined prospectively by diagnostic accuracy with and without nuclear medicine consultation.

**Protocol Selection in Nuclear Cardiology**

The benefits of nuclear cardiology consultation are already well established, in the form of risk assessment by cardiologists before radionuclide imaging.[9] With pre-screening of patients for stress-rest myocardial perfusion imaging, patients that would benefit from stress only protocol could be selected appropriately, which could decrease the hospital stay. More importantly, there may be a difference in the way images are interpreted, when all clinical information, including physical examination, ECG findings, medication history, and medical as well as surgical history are not taken into consideration.[5,6]

**Clarifying Cognitive Impairment with the help of Nuclear Neurology**

Improved characterization of neuropsychiatric pathology is another beneficial use of the nuclear medicine consultation. In cases of cognitive impairment in either the inpatient the differentiation of neurodegenerative disease, vascular disease or psychiatric illness can be difficult on cerebral perfusion SPECT or $^{18}$F-FDG PET.[10] In such cases, formal consultation can allow a more tailored interpretation of the findings. In normal pressure hydrocephalus, correlation with physical examination following lumbar drainage of CSF has been shown to impact diagnosis, and can help the interpreting physician in radionuclide cisternography interpretation.[11] Similarly, in brain death evaluation, collaboration with the primary neurologist can help correlate the clinical findings with scan data to more appropriately diagnose brain death.[4]

**Consulting for Thyroid Dysfunction**

In the outpatient setting, the advantages for nuclear medicine consultation are well known.[12] Primarily, the role in the outpatient setting for the nuclear medicine consultation has been for the management of thyroid disorders including differentiated thyroid carcinoma, toxic multinodular goiter, and Graves’ disease. Ablation with $^{131}$I and postablation monitoring with serum markers and follow-up radiiodine imaging continues to be a common reason for the nuclear medicine consultation.[13] However, consultation prior to any diagnostic nuclear medicine study in the outpatient setting, can have the added value of providing more clinical information to the image interpreter.

**Inpatient Consultation for Routine Nuclear Medicine Studies**

Other routinely performed studies including hepatobiliary, renal, and gastrointestinal scintigraphy as well as infrequently performed studies imaging are commonly utilized by the general practitioner service. For these studies imaging technique as well as radiopharmaceutical, type can be influenced by the patient-specific clinical information. For example, in hepatobiliary imaging, hyperbilirubinemia can be an indication to use $^{99}$mTc-Mebrofenin instead of $^{99}$mTc-Disofenin; and based on the fasting status of the patient, cholecystokinin may or may not need to be administered.[4] In renal scintigraphy, whether diuretic or ACE inhibitor study needs to be performed can be essential if obstruction or renal artery stenosis are clinical questions to be answered.[4]

In some patients, these studies may not be warranted at all, due to physiologic factors limiting the bio-distribution of radiotracer, or inability of a specific imaging technique to answer the clinical question at hand. Lastly, as with the other studies, image interpretation can greatly improve with tailored clinical history by the consulting nuclear medicine specialist. Although we need more evidence, studies to look at the diagnostic accuracy with and without tailored clinical history could further elucidate this.

**Conclusion**

Because of increasing scrutiny on ordering providers to curb the number of diagnostic imaging studies that are ordered,
instead of a more streamlined use of imaging studies, there is an overall reluctance to ordering imaging studies altogether. This is exacerbated by the general practitioner’s workload and unfamiliarity with nuclear medicine. General practitioners must remember that nuclear medicine is a physiologic, rather than a structural, imaging modality. Thus, like many medicine subspecialties, it requires careful consideration of all relevant clinical information including history, physical examination, and supportive diagnostic testing. The importance of clinical information in the interpretation of other diagnostic imaging modalities has been previously described. However, further research into the impact of this crucial information on the interpretation of nuclear medicine studies and its impact on patient care needs to be better characterized. Nevertheless, there is considerable potential value to the nuclear medicine consultation in both the inpatient and outpatient settings; not only for selecting the appropriate test but also for more accurate image interpretation. In this way, nuclear medicine consultation can surely have major input in the clinical decision-making process on the wards and the clinic, and warrants further consideration.

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Conflicts of interest

There are no conflicts of interest.

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