Implementing Multimodality Imaging in the Future

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BACKGROUND

Multimodality imaging (MMI) has been at the forefront of discussions for more than a decade, and the 2015 Core Cardiology Training Symposium (COCATS) guidelines published in May 2015 (1) have further reinforced its importance. Nearly everyone agrees that MMI training is imperative, and most fellows in cardiology programs who are interested in careers in noninvasive imaging have expressed strong interest in acquiring such expertise and eagerly ask about its formal inception. All of the iJACC editors come from university-based academic health centers, and we routinely find that many of our junior faculty colleagues are already trained in and practice in 2 or more imaging modalities. Employers, especially in nonacademic settings in the U.S., are not able to afford the luxury of “solo imagers” and thus seek cardiologists who can handle multiple imaging modalities. In this sense, newly graduating fellows who concentrated on “single-modality” imaging during their training might be at a disadvantage. Possessing skills in at least 2 modalities appears to be the minimal requirement for finding employment as a noninvasive cardiologist at most practices. This varies by jurisdiction, but usually echocardiography and nuclear imaging are sought, but the ability to do computed tomography (CT) has also become highly desirable. However, despite all of the interest and goodwill, the practical implementation of MMI training in the U.S. has been slow because of practical and logistical issues during 3-year fellowship programs. The future of its rapid implementation into clinical practice appears as clouded today as it was a decade ago.

We as Editors of iJACC feel that imaging modalities, despite originating individually, should no longer be seen as silos. Cardiovascular imaging is fundamentally about the information in the image, not how it is acquired. MMI is a rational endpoint of this position and should be the preferred aim for the future. To speed up the philosophical debate concerning MMI and hoping to stimulate its growth, we thought that we should lay down our vision, however aspirational at this time, about how to best implement MMI. However, this is a consensus opinion document that is simply a viewpoint of the group, and it should not be taken as competing with any society policy or guidelines. The recommendations on MMI from COCATS 4 remain the primary guidance for fellow training (1). In this Editor’s Page, we discuss only the opportunities and challenges in the field and suggest a possible working plan for extracting the maximum high-quality imaging training within the prescribed duration of a cardiology fellowship. It does not provide any timeline for implementation, and is our view of one of the many possible pathways to efficient implementation. We
do not prescribe level III training in all modalities as the basis of MMI but want multimodality imagers to be the expert practitioners of appropriate imaging modalities and to be able to precisely define the right test for the right patient at the right time. We also believe that well-trained imagers should be able to seek further expertise during an additional year of advanced imaging training (a fourth year) or gain experience during their early years of consultancy. This concept of maturity remains similar for all disciplines of medicine, especially for the procedural specialties.

CORE PHILOSOPHY

We believe that a pivotal challenge to wider acceptance of MMI is the creation of a sufficiently trained cadre capable of handling multiple imaging modalities in clinical care. The need to train fellows adequately during a general cardiology fellowship program arises, as the majority of training programs are 3 years in duration. This philosophy envisions, as a practical necessity, 2 levels of imagers: a larger mass of multimodality imagers (the base of the pyramid) who will provide the day-to-day, frontline-level imaging, and a smaller mass of imagers with higher levels of training (the apex of the pyramid) who will provide tertiary-level expertise in imaging and will be consulted by the frontline cadre of imagers. The frontline multimodality imagers would handle up to 3 or 4 modalities, with a skill set that can provide competent day-to-day imaging (equivalent to level II training, as that is the minimum level of expertise necessary to independently perform and report imaging studies). The expert with the highest level of training (currently level III) in 1 or more specialties, for which an extra dedicated year of training is required, will provide the next level of expertise. We believe that the latter level of training (equivalent to level III) is not necessary for providing most imaging services needed in daily practice, and MMI must not be equated with acquiring multiple level III credentials. Therefore, adding a fourth year of training in imaging to create the majority of frontline multimodality imagers might be overkill. Training in MMI in the fourth year of imaging training (which in reality is 7 months of regular fellowship imaging training plus 12 months of dedicated fourth-year imaging training, for a total of 19 months of imaging training at a minimum) allows certain dedicated noninvasive cardiologists to be level III MMI imagers: the imaging experts who direct laboratories, advance the science of imaging, and provide leadership in specialty societies. Thinking about the problem in this way will allow us to settle on the optimum duration and degree of training needed for competent, everyday imaging without expecting an ever increasing, open-ended apprenticeship. Finally, with concurrent modality training, our proposal for MMI is designed to fit within the training distribution framework allocated for the 3-year fellowship program without sacrificing any other valuable training time.

The proposed document was inspired by the previous 2 MMI documents: the seminal 2008 MMI guidelines (2,3) that suggest the feasibility of incorporating MMI training within the confines of a routine 3-year fellowship and the 2015 MMI document (1) that considers the challenges of incorporating substantial training within the fellowship program duration. Consistent with the aforementioned core philosophy, any MMI proposal must maintain conformity with COCATS documents and modality-specific statements. Such a proposal would need to be geared to the idea that patient-centric imaging will force both training and clinical testing to breach modality and technological boundaries. Thus, programs would need to conceptualize the ability and logistics to cross-train in 2 modalities at a time. Finally, although not on the horizon at present, such an MMI training proposal should help pave the way for a single MMI board certification in cardiovascular imaging in the future.

WHY IS NOW THE RIGHT TIME TO INCORPORATE MMI TRAINING?

With rapid advances in imaging technology, current fellows in training and future consultants will frequently be required to use MMI in patient care. Generalists will routinely use and interpret imaging in their daily practice for diagnosis, prognosis, and therapy, whereas proceduralists will increasingly find that the appropriate use of imaging is indispensable for high-quality care. Imaging is finding ever greater use in intervention and electrophysiology laboratories, and newer applications are being introduced all the time. It is likely that all physicians will benefit from greater understanding and application of imaging. Technology would eventually blur the artificial separation between consultative, diagnostic, and procedural cardiologists. Skills are already crossing boundaries, and every cardiologist will need to be able to understand, use, and interpret imaging to a greater degree than at present. Cardiologists who are not primary imagers, such as interventional, electrophysiologic, and heart failure cardiologists, would use complementary imaging skill sets to a much greater extent. A strong foundation in MMI, but not
necessarily reaching level II for most, would thus become the core of every cardiologist’s fellowship training, just as the cognitive part of fellowship training is at present.

MMI comes at a time when there are many divergent forces buffeting imaging. First is the fragmentation of imaging expertise into narrow, modality-specific areas. Each of the 4 major modalities (echocardiography, nuclear imaging, CT, and cardiac magnetic resonance [CMR]) was developed independently, and we continue thinking about them as individual silos, partly also because they are frequently not colocated at training institutions. It takes longer to master any individual modality because training duration is increasing in proportion to complexity. Moreover, with the increasing complexity of each individual modality, fewer cardiologists have had the time or training for the ever increasing level of specialization, which also perpetuates the silo mentality, in that the few cardiologists who have the most training often have less time to learn broadly about other modalities. This degree of specialization, although needed to advance the field and expertise, is a double-edged sword that can limit the wider understanding and application of different modalities, each of which has unique strengths and weaknesses.

In contrast, the imaging modalities must continue to focus on and embrace synergy and integration. This is already happening in terms of technological evolution, wherein information about structure, function, physiology, and pathology is being effectively integrated, combining modalities such as single-photon emission tomography plus CT, positron emission tomography plus CT, positron emission tomography plus CMR, and CT plus fractional flow reserve (1). Integration will evolve to become the core of patient-centric imaging decision making and would be required of future multimodality imagers. Imaging cardiologists would be expected to have the ability to perform the best test for the most optimal patient outcome using tools from a broadly integrated imaging toolbox. This approach is imperative if we are to provide efficient, cost-effective care. To quote a previous JACC Editor’s Page, “the application of a given modality should be dictated by the needs of a particular patient rather than the expertise of a particular cardiologist” (4). Future specialists must by necessity be well versed in multiple skills, and there will be a premium for consultants who can perform and interpret cost-effective and concise diagnostic testing strategies and are trained in cognitive skills to synthesize a wide variety of information into a rational management plan.

Furthermore, there is a belief that too much imaging is being done at significant cost and without strong evidence that this amount of imaging is needed or indeed improves outcomes. The future of imaging will depend on demonstrating the value of imaging in terms of outcomes, and we are just beginning to see some positive data (5). Producing good patient outcomes will very likely depend on the availability of clinicians who understand the nuances of multiple imaging modalities, who can perform optimum quality imaging, avoiding duplication, and who would answer clinical questions with the least testing undertaken in a cost-effective manner. Cardiologists, who are well trained in a variety of imaging modalities through a well thought out, comprehensively structured general cardiology fellowship program, would best form the bulk of the future imaging workforce involved in patient care. This is expected to prevent the stacking of diagnostic tests, reduce the cost of imaging, minimize risk and discomfort, and improve outcomes.

Finally, cardiology fellows are increasingly interested in embracing MMI, and potential employers are encouraging prospective candidates with the ability to practice in multiple imaging modalities. Except for selected niche areas, it is less likely that the future marketplace will be able to support imagers who practice in only 1 imaging modality. However, only a few general cardiology fellows are willing to add more years to their imaging training, which would be required under the sequential (or serial) mode of training; 15 months of training is currently required for level II training in 4 imaging modalities, and up to 42 months of training is needed for level III certification. This is clearly unrealistic. The 2008 COCATS MMI task force suggested that novel methods of training would be needed for fellows to develop higher levels of expertise in more than 1 imaging modality in a 3-year fellowship (2). Most important, competency-based learning and training, which emphasize successful graduation on the basis of clearly articulated and rigorously evaluated competency during training, rather than on only the duration of training or the number of studies performed and interpreted, allows newer pedagogy in imaging pathways. All of these developments allow the possibility of integrating a formal MMI training pathway into 3-year general cardiology fellowship programs and might lead to the establishment of parameters for well-rounded multimodality imagers.
THE IDEAL MULTIMODALITY IMAGER

A multimodality imager, in our opinion, is not a person who can simply perform more than 1 imaging modality or can use many imaging tests to obtain information (Table 1). The ability to perform and read multiple modalities does not necessarily produce a better imager (6,7). Our idea of a multimodality imager is more rigorous, involving the ability to perform imaging on the basis of outcomes, to avoid the costly gauntlet of multiple testing, and, more important, to add value to patient care decisions. A multimodality imager should be able to develop strategy- and outcome-based thinking through a well-defined, rigorously implemented training program in the 4 commonly used imaging modalities. We envision this practice to involve more than reading images. Using a wide armamentarium of imaging technologies, an imager should be able to evaluate the need for imaging in any given clinical scenario; help select the best test to answer the clinical question with the least amount of imaging, thus educating and providing consultation to the general clinicians ordering imaging tests; substitute inappropriately ordered tests with a more optimal one; perform high-quality imaging on the basis of appropriate use criteria; and interpret and report imaging studies expertly, effectively, and expeditiously.

PRINCIPLES FOR RESTRUCTURING THE MMI TRAINING PARADIGM?

We believe that fellowship training programs should encourage MMI training (Tables 1 to 3) that envisions patient-centered cardiovascular testing. Imaging is organized around the central clinical question that needs to be answered, and the modality chosen is just one tool in the process. Individual modality-focused professional societies have clearly defined standards. It thus becomes a question of designing the logistics of fitting this content into the training program rather than recreating any particular MMI content. Just like selection into any other advanced training, not every fellow needs MMI training, and we could make sure that only those sufficiently motivated for careers in noninvasive imaging would be encouraged into this track. The following general principles might help in planning for MMI training in future.

We believe that it should be possible for cardiology trainees interested in noninvasive imaging careers to get a 12-month cardiac imaging training in 3 or 4 common modalities (echocardiography, nuclear imaging, CT, and CMR) during their 3-year general cardiology fellowships (Table 2), with the flexible rotations tailored to their long-term goals. This has traditionally required 15 months of training sequentially in individual modalities, but it could be possible in 12 months.
if concurrent training is allowed. Within the ambit of the COCATS requirements, training should be flexible and in line with future career goals and needs.

Fellows not interested in MMI careers can still adhere to the current requirement for 7 months of basic training in imaging. However, given the importance of thinking in 3 or even 4 dimensions and the role of imaging in invasive procedures, it might be advantageous for fellows to have the opportunity to access longer training in imaging if they so choose and if program logistics allow it.

Fellows choosing noninvasive imaging careers could use this year of imaging training to achieve level II expertise in 3 or 4 modalities; training in 4 modalities within the year is challenging and would require considerable planning, coordination and, importantly, simultaneous training; we see this option being offered only to the most motivated fellows in a limited number of institutions that have large imaging practice infrastructure, very high volumes, and multimodality expertise with cutting edge facilities. While fellows often take time to decide on a career path, these fellows could be encouraged to start planning for this option early in the fellowship, preferably by the end of the first year.

Fellows interested in attaining more in-depth expertise in 1 or more modalities should aim for level III, which will usually require an extra year of training. Ideally, this should be planned early, synergistically, in the context of the total 2 years of training in imaging.

Those interested in procedural careers (interventional or electrophysiology) could benefit from being more versed in imaging than is possible in the current environment; they may modify their choices of modalities if it helps with their long-term career choices without needing to achieve level II expertise in any modality except echocardiography. For instance, understanding nuclear myocardial perfusion imaging and CT angiography might enhance coronary interventional decisions; a valve interventionist may elect to focus on CT or magnetic resonance imaging in addition to echocardiography. An electrophysiologist could find a deeper understanding of CMR or CT helpful in prognostication, localization, and targeting of foci for ablation. Finally, fellows interested in pursuing careers in heart failure might choose to concentrate on echocardiography and CMR.

Fellows should be taught early on to move away from modality-centric imaging and toward more patient-centric imaging. They should consider modalities as tools in the armamentarium of the imager used to obtain the best clinical answers rather than as independent and competitively exclusive bunkers. Faculty members must also inculcate this philosophy into their trainees; we should not be training echocardiographers, nuclear cardiologists, or CT and CMR specialists but comprehensive imagers. All imaging could be treated as a single modality with a finite training period. Unifying imaging around the image information rather than how it was obtained can generate creative ways of structuring training time and competency-based evaluation.

Competency rather than the length of training should determine when a fellow is ready for MMI. We believe that 12 months of MMI training should be enough to qualify someone as a multimodality imager engaged in routine patient care. It has been mandatory for fellows to spend an extra year (fourth year) to gain added expertise in procedural specialties (intervention and EP). However, more than 1 additional year would be needed to attain traditional level III competence in all imaging modalities, but this is quite impractical. With appropriate planning and logistics, level II in multimodality imaging can be achieved in 1 year with added comprehensive expertise if planned.

### Table 2: One Template for MMI Training Within a 3-Year Program

<table>
<thead>
<tr>
<th>Modality</th>
<th>Level</th>
<th>Traditional</th>
<th>Total</th>
<th>Dedicated</th>
<th>Shared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echocardiography</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Nuclear</td>
<td>2</td>
<td>4-6</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>CMR</td>
<td>2</td>
<td>3-6</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cardiac CTA</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total training</td>
<td>15</td>
<td>15 spread over 12</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

MMI (level II in 3 or 4 modalities) can be encapsulated within a 12-month period using shared training months. Success will of course depend on fellow motivation and facilities at the center.

CMR = cardiac magnetic resonance; CTA = computed tomographic angiography; MMI = multimodality imaging.

### Table 3: What Should a MMI Trainee Be Able to Do Competently?

1. Add demonstrable “clinical value” to patient care with imaging.
2. Provide high-quality interpretation of imaging data expertly and expeditiously.
3. Understand the strengths and weaknesses of imaging modalities in great detail and competently use them in day-to-day practice.
4. Understand prognosis and outcome data with imaging results.
5. Advise on need for imaging and best imaging strategy (efficient, cost effective, and safe) to answer the clinical question.
6. Discuss and substitute the right imaging test or modality for inappropriately ordered testing in consultation with the referring clinician.
7. Perform high-quality imaging consistent with current guidelines and appropriate use criteria and avoid duplication.
8. Provide an “outcome-based strategy” for diagnostic testing.
for 2 years. In this regard, there is a unique difference between imaging and other procedural specialties. In both interventional and electrophysiology training, fellows use the extra year to learn and practice techniques they did not learn "hands on" during the regular 3-year general cardiology fellowship. For example, although they may be exposed to cannulation of the coronary arteries, they do not participate significantly in crossing lesions, dilating, or stenting. The same is true for electrophysiology. However, in imaging, fellows perform and train in nearly all the same techniques in the 3-year fellowship in which they would further train should an additional fourth year become necessary. The extra year in this case adds to their expertise (more numbers, variety, and experience) in largely the same techniques they have learned before. The number of cases imaged and the spectrum seen during the level II experience in imaging in the 3-year fellowship should provide a reasonably robust platform to allow them to perform and read independently. In-training testing of knowledge (not only after graduation) in addition to the required time and number of cases would be a welcome addition to evaluating competence. Creating rigorous level II training in MMI (with the possibility of MMI certification when the time is ripe in future), would make these cardiologists even more capable in the practice of high-quality imaging.

Because the foundations of cardiovascular imaging remain largely similar regardless of the modality, MMI training should exploit the general principle of shared training and taking advantage of colocation of imaging modalities. Such an approach allows concurrent rotation through 2 imaging modalities. We should be able to provide operational flexibility to execute this format. For instance, whereas cardiovascular imaging programs may combine CT and nuclear cardiology or echocardiography and CMR training together radiology-heavy programs may share CT and CMR training side by side. In contrast, programs with lower volumes may allow training in echocardiography and nuclear imaging during the same workday or CT and CMR reading during the same session. Imaging training can also share curricula across other non-imaging disciplines, as previously outlined (2) (e.g., didactic sessions that teach coronary anatomy for invasive coronary angiography and CT angiography together, or pulmonary and coronary venous anatomy in electrophysiology and imaging together). The exact strategy for sharing in any given situation could be determined by local resources and infrastructure.

Shortening of training duration and concurrent training raise the specter of suboptimal training. Rigorous training requirements and comprehensive real-time evaluation and testing to ensure quality training can protect against inadequately trained fellows and permit remediation. However, we believe also that the incorporation of an early-in-training in appropriateness, quality, and cost-benefit concepts into every test performed would be a great defense against inappropriate use and poor outcomes. The strongest barrier against inappropriate use, in our opinion, is the training ingrained with a culture of evidence-based action. We should emphasize learning and the incorporation of test appropriateness as to why one modality is more suited than another for a specified clinical question. It should be helpful for fellows to index their tests to some measure of quality (test selection, performance, interpretation, and reporting (8)), so that they understand what a quality test means and how a suboptimal test has adverse consequences, such as retesting, delay, or morbidity.

UNANSWERED QUESTIONS AND PITFALLS IN IMPLEMENTING MULTIMODALITY IMAGING

As the editors of an imaging journal, our bias is naturally toward fostering the development of imaging. That being said, we are also aware that there are many unanswered questions in this arena. What is the demand for MMI in the community, how will it be affected by health care reform, and how is the field of imaging viewed in future? Even though forecasting these trends in a rapidly changing national health care environment is fraught with uncertainties, training programs can adapt as needed and evaluate what can be offered locally or collaboratively. Our proposal does not place additional burden on fellows in terms of duration of training or added cost and still positions them to effectively use whatever imaging tools the marketplace is likely to support. Some may question whether fellows can handle so much imaging in a 3-year period, but we do not see that as an issue, as long as there is a well-structured training and evaluative program in place. Fellows absorb a lot more at this stage of their careers and are facile with technology. Many fellows have been actively pursuing MMI training anyway for the past few years, and many programs have taken it upon themselves to find the time to allow it within the COCATS training guidelines. Our proposal outlines only 1 such pathway for the additional 5 months (i.e., in addition to the current minimum of 7 months of basic imaging training). Using time for electives and partly overlapping
clinical research months within the imaging months might provide more flexibility for programs to encourage this approach. It is reasonable to ask how many centers can provide this level of training, and the answer may not be as encouraging as we would like at this time (9). However, many of the larger centers have already incorporated various facets of MMI and train their imaging fellows to level II in 1 to 4 modalities. For those centers that need time to embark on this pathway, they can harness other resources to enhance their ability to provide this training (2). Both the COCATS as well as this proposal encourage using a multitude of mechanisms, including audiovisual materials and seminars, and continuing medical education sponsored by individual societies, to obtain the didactic part of the training. Centers can collaborate and cross-train fellows or use online resources to provide adequate exposure to the cognitive parts of imaging. Finally, one may ask how we will know if it is working. We are entering a data-driven era, measuring efforts, quantifying return on programmatic investment, enduring scrutiny from payers and regulatory agencies, and tracking outcomes. Hospitals are adapting to mining these variables, and that will apply to MMI as well. Such data will define the place of and need for MMI in the future.

CONCLUSIONS

We and many others in the imaging community see an advantage in training well-rounded multimodality imagers. It is likely that such imagers will better understand the strengths and limitations of any test. These imagers can be change-agents who will guide and teach their colleagues to optimize the chain of diagnostic testing. Answering clinically relevant questions expeditiously with the test that has the best risk-benefit-utility profile might improve outcomes more than the current scattershot approach to testing, whereby local expertise rather than what the patient needs becomes the de facto strategy.

With rapid advances in imaging technology, current fellows in training, who will be the consultants of the future, will be asked to play a more comprehensive role using imaging modalities in patient care. Noninvasive cardiologists will routinely use more imaging tools in their daily practice for diagnosis, prognosis, and therapy, and they will need to understand these tools in greater depth. Procedural specialists would need to learn to interpret 3-dimensional or 4-dimensional multiplanar imaging as part of their procedures, and it is therefore likely that they will use and need to understand imaging to a greater degree than before. A strong foundation in MMI will need to be at the core of their fellowship training as well.

Although MMI has been proposed for more than a decade now, it is time to start thinking seriously about wider adoption, training, and application of MMI.

The main current limitation to transitioning fellows into MMI, in our view, is the unrealistic length of training that is expected of them. Incorporating most of the routine aspects of MMI into the regular 3-year fellowship program seems to be the logical way to bring MMI to fruition. This would need to be anchored by an intense emphasis on high-quality training and rigorous competency-based evaluation.

A cadre of cardiologists, who lead imaging laboratories, training programs, and research centers and indulge in complex interventional imaging or consultative practice would need more specialized and advanced training in modality-specific imaging.

Training in imaging will radically change over the next 10 years. Medical schools have begun to incorporate ultrasound, CT, and CMR training in their first-year curricula. It is expected that all medical students would be trained at the standard equivalent to level I training for whole-body imaging and use newer handheld imaging devices as part of bedside examinations. MMI will drastically enhance the physical examination and will undoubtedly become second nature for graduating physicians.

The last word on MMI is still awaiting some date in the distant future. The imaging community has a significant stake in getting this right, and there undoubtedly are multiple ways to formalize and incorporate MMI into practice. We are sure the imaging community has much to say on how best to do this, and many views may be in significant variation to our suggestions. This JACC piece is a platform for discussion, and we hope it stimulates ferment and an exchange of ideas. Let the discussions begin. We are looking forward to your comments, critiques, modifications, and suggestions.

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