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# Refinement of the Facility-Level Medical Technology Score to Reflect Key Disease Response Capacity and Personnel Availability

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**ABSTRACT** This paper presents a second look at the computation of the Medical Technology Score (MTS), a metric designed to convey the relative technical competence of a health facility. Modification of the score to reflect local disease burden is discussed, as are its intended interpretations. Extensive data collection on up-to-date equipment and personnel resources must be undertaken before the MTS can become useful as a policy-relevant tool.

**INDEX TERMS** Biomedical equipment, technology management, appropriate technology, inventory control, technology transfer, health information management.

## I. INTRODUCTION

Medical equipment in developing world health facilities is largely insufficient and inappropriate, resulting in reduced capacity for hospitals and clinics, suboptimal outcomes for patients, and wasted money for donors and investors. Rather than merely emphasizing a ''lack'' of equipment, the international health community would do well to cite incongruity between facility needs and inflow of supplies and equipment. Challenges range from direct operational hurdles such as incompatibility with local power sources [1] to less obvious considerations, such as optimal operating temperatures and local infrastructure shortfalls that make temperature control unavailable in certain types of facilities.

Equipment donation is currently the largest source of equipment for developing world health facilities. However, the majority of these instruments fail within 6 months of arrival, with others never being usable [2]. Organizations such as Engineering World Health (EWH) approach the problem of equipment failure from a training and repair standpoint. There is a need for simultaneous development of policy-relevant measuring tools to help gauge the effectiveness of capacity-building efforts and to highlight areas of need for the purpose of setting priorities in health technology management at national and local levels.

## II. THE MEDICAL TECHNOLOGY SCORE

### A. BACKGROUND

In a previous work [3], Fatunde and Bhatia introduced the Medical Technology Score (MTS), a quantitative metric that describes the ''level of technology'' in a given facility by capturing the adherence of the facility's equipment inventory to a baseline international standard inventory. In order to ensure consistency, it is imperative to establish a scheme for classifying health facilities in a given nation according to a recognized standard, such as that of the World Health Organization (WHO). A summary of the suggested calculation procedure is given in Table I.

The five steps in the originally proposed MTS calculation [3] are listed in Table I. Due to the need for additional qualitative considerations in computing a score at the national level, the national score is excluded from the equations in this paper. See the appendix for further information regarding calculation of the original MTS.

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### *B. A NEW DEFINITION*

Context-specificity is a theme that has long been highlighted in global health [5]. In the arena of health technology, "context…refers to linking the correct medical device with its corresponding health need to maximize its effectiveness." [6].

**TABLE I. MTS calculation process.**

| | |
|---|---|
| 1 | Identify the top causes of local mortality/morbidity |
| 2 | Use WHO guidelines for equipment necessary to diagnose and treat these conditions |
| 3 | Combine with WHO standards for health care facilities to create an "ideal inventory" |
| 4 | Compare national inventory to ideal inventory to obtain the compliance ratio<br>*Note: A category score is the average of the facility scores within the category* |
| 5 | Weight by "essentiality" score of inventory items to create the facility score. Weight average facility scores of different facility categories by density of facilities [4] to create a dimensionless national "score" |

**TABLE II. Original MTS equations.**

| | | |
|---|---|---|
| Item | $score_A = \frac{x_A}{y_A}$ | (1) |
| Facility MTS | $score_{hosp} = \frac{\sum_{i=A,B,C...}(score_i)(e_i)}{n}$ | (2) |
| Category MTS | $score_c = \frac{\sum_{i=1}^{N_c} score_{hosp,i}}{N_c}$ | (3) |

where
- $x_{iA}$ is the quantity of item A in facility i
- $y_{iA}$ is the ideal quantity of item A for a facility in the same category as facility i
- $score_i$ is the score for a single item i in a facility
- $score_{hosp}$ is the score for the entire hospital or unit being considered
- $e_i$ is the measure of "essentiality" for a given item. This measure is based on the Fenningkoh and Smith model, which uses a point system to evaluate items basec on function, risk, and required maintenance [7]
- $score_c$ is the aggregate score for each category of health facility
- $N_c$ is the total number of categories in category c

In order to ensure appropriate comparison of MTS values among a wide range of facility types in different countries, the MTS must take into account the factors that are most relevant to a given location. A metric that ignores local needs would simply result in low scores in developing countries as compared to facilities elsewhere. A flat international comparison of this type would tell us only that the developing world tends to operate with fewer devices, which on average tend to be less "high-tech" than in other nations: hardly a beneficial insight.

Instead, the premise of the MTS is a locally ideal set of circumstances for a given facility type in a given country, and more specifically in a set of conditions (demographic, geographic, etc) that have been defined for a certain locale and that give insight into the health needs of the people in the facility's catchment area. In other words, the local ideal should be tailored towards the corresponding "disease personality" of a given area.

The goal of this revision of the MTS is to better reflect whether a facility is technologically prepared to address the conditions that it is most likely to see. From a measurement perspective, two manipulations to this effect can be made to the MTS formula: a new term encapsulating condition-specific capacity can be added to the calculation, or this "capacity evaluation" can be pre-embedded in what constitutes an ideal inventory. This can be achieved by considering the equipment necessary to address the relevant diseases, analyzing patient traffic due to those conditions, and increasing quantities or adding additional inventory items to the ideal inventory in order to account for the foreseeable increased need.

The first option, except in the case of a binary (and thus arbitrary) variable, will likely still involve a tally of equipment. The second, which requires more analysis, assumes that possession alone of the aforementioned equipment renders a facility able (to a certain extent, as specified by the facility's score) to appropriately treat those conditions, without regard for the severity of the condition, whether or not there are trained personnel on hand, and other important considerations that are certain to impact actual patient outcomes. Furthermore, the combination of multiple factors into a single figure obscures the facility's "disease readiness," which, if accurately determined, is a useful piece of information on its own. In order to leverage the most beneficial aspects of each method, the second iteration of the medical technology employs the following (see Table II and Table III for the relevant equations).

- Inclusion of medical equipment by condition (this was mentioned in Reference 1, but was not included in the example given in Ch. 3). This is represented by an expanded ideal inventory that includes both primary care needs and treatment requirements for the most important causes of mortality/morbidity.
- Inclusion of a term corresponding to the number of health staff per patient at the facility, with different weights assigned to professionals at different levels of training.

The second point takes into account both the need to include human resource assets and ease of measurement—it requires the evaluator merely to tally and classify personnel and equipment, rather than to make subjective judgments at the point of measurement. The personnel term is based on employment for the purpose of measurability, but accuracy of this term is likely to waiver based on challenges such as absenteeism. Years of experience, if used as the coefficients in Eqn. 6a, might provide useful information. In particular, using years of experience allows for equivalence between different combinations of personnel inputs (the experience of 3 nurses and 1 physician might be as valuable as that of 5 nurses and 2 physicians) and is thus an approach that is friendly to the concept of task-shifting. However, the relationship between experience and equipment performance is unlikely to be linear past a certain baseline level. Thus, the personnel weights that factor into the intermediate personnel score should ideally be determined empirically.

**TABLE III.** New MTS equations.

| | | |
|---|---|---|
| Item | $score_i = \frac{x_{i,(A,B,C...)}}{y_{i,(PHC,CondA,CondB,CondC....)}}$ | (4) |
| Equipment | $score_{equip} = \frac{\sum_{i=A,B,C...}(score_i)(e_i)}{n}$ | (5) |
| Personnel | $x_{P,i} = \frac{d(D)+n(N)+(l)L+(p)P}{Patients}$ | (6a) |
| | $score_{pers} = \frac{x_p}{y_p}$ | (6b) |
| Facility MTS | $score_{hosp} = (score_{equip})(score_{pers})$ | (7) |
| Category MTS | $score_c = \frac{\sum_{i=1}^{N_c} score_{hosp,i}}{N_c}$ | (8) |

where

- *PHC* denotes those pieces of equipment that are essential for basic primary healthcare
- *CondA* is a single condition determined to have a high burden of disease in the country or in the area of the facility. Additional conditions will be represented by additional terms designated *CondB*, *CondC*, etc
- $score_{equip}$ is the subscore that accounts for equipment only
- $x_p$ is the number of medical personnel employed who are trained to operate health equipment
- $y_p$ is the number of trained medical personnel required to properly operate the equipment present, as determined by external assessment
- *d,n,l,* and *p* are empirically-determined personnel weights for doctors, nurses, laboratory technicians, and pharmacists, respectively
- *Patients* is the recorded or estimated number of patients served by (in the catchment area of) the facility
- All other variables retain their original meaning.

For the purpose of developing ideal inventories, WHO guidelines and the recommendations of local medical experts will be used. However, these can and should be augmented by national standards where they exist, particularly when the MTS is used for internal health policy planning.

## C. INTERPRETATION

A perfect MTS score is quite intuitive; it suggests that a facility contains all of the requisite equipment (and the staff to operate them) necessary to provide a certain standard of primary care and also to attend to those conditions that represent a high burden of disease in the community.

Less-than-ideal, and particularly midrange, scores present a greater analytical challenge. What is to be done once a facility learns that it has a score of 80%? 50%? Do identical scores have any meaning across country lines? Questions such as these underscore the importance of proactive use and integration of this tool (which is simply that—a tool) into existing or emerging health technology policy. By design, the MTS is most meaningful as a comparative metric when computed for multiple (and if possible, all) facilities within a single nation or sub-national administrative region. Calculation of a country-level MTS involves consideration of several qualitative factors beyond those included in the quantitative inventory and personnel calculation. Furthermore, the results of international MTS comparison are unlikely to yield policy-relevant or useful results and might even be arbitrarily and subjectively defined, given differing levels of prioritization of, and resources dedicated to, health technology [8].

To maximize the usefulness of the MTS, local health administrators may find it useful to conduct a thorough analysis of health problems, hospitalization and outpatient treatment statistics, human resources, and procurement protocol, and then identify a level that represents the target MTS score for facilities under its jurisdiction. Facilities are also encouraged to set their own internal objectives based on their more finely detailed knowledge of staffing and patient flow. Ideally, the target for each and every facility, regardless of location, is 100%. In practice, setting moving targets (within specified timeframes) and delineating the remedies needed to help certain facilities approach and meet those goals can serve as a useful method of ensuring steady progress that is guided by local needs. Visualization and large-scale (national) comparison of MTS values for several facilities using mapping or other tools can also help policy makers set priorities for intervention and resource allocation.

Perhaps the greatest use of the MTS metric lies in its ability to help measure and predict the impact of adjusting certain variables. Activities such as repairing nonfunctional equipment and acquiring new equipment have the effect of increasing a facility's MTS. Acquisition of a surgeon in a facility that sees a high proportion of trauma or accident cases should be reflected by a change in that facility's score. Further development of the MTS aims to capture such effects. However, the tool only becomes useful when it can be used to paint an accurate and *complete* picture of needs and capabilities. Regular supply of information about facilities, equipment, and personnel, as well as capacity-building initiatives, is therefore essential.

## D. IMPLEMENTATION

A solid initial theoretical formulation of MTS is critical before any practical exercise will produce the desired results. However, it is useful to consider and plan for the logistical requirements of collecting the necessary data. The information required corresponds to what is needed to create a useful estimate of the quantities captured in the MTS equations (Table IV).

**TABLE IV.** Necessary data.

| | |
|---|---|
| **Facility Information** | • personnel*⁺<br>• patient flow⁺ |
| **Equipment Information** | • equipment specifications (down to serial number) *⁺<br>• quantity (if multiple)*⁺<br>• original equipment price*<br>• age*<br>• equipment density (geographical) ~<br>• average usage (number of patients, number of times used per day)⁺<br>• input costs (power, consumables, staff, etc.) per use⁺<br>• place of origin*<br>• donated or not? *<br>• functional or not? (source of problem if applicable)<br>• number and cost of repairs* |

*To be obtained from administrators
~To be obtained from national information or international guidelines
+To be observed/derived

 

When attempting to carry out a practical MTS calculation, careful consideration of the sphere and scope of evaluation is in order. If a goal of using MTS is to guide policy making and central allocation decisions, it may make sense to focus on public hospitals. Comparison to health facilities in other sectors should be limited and cautious, as the decision-making processes that influence equipment purchase and distribution are totally separate and independently motivated in the private and other sectors.

In practice, equipment information is the most straightforward to collect, as it can be objectively observed even in the absence of detailed records, and functionality can often be verified immediately. An inventory may be taken manually or electronically (using inventory management software). It is particularly important to capture information (such as dates of manufacture, donation, commissioning, etc.) that may help to estimate the remaining lifetime of the equipment [9]. A member of the biomedical engineering or clinical engineering staff should be present if and when possible in order to supplement observed information with equipment history and usage statistics. It is also important to consult clinicians during the process of data collection, as they are most likely to be most knowledgeable about equipment function and specific reasons for/history of any observed malfunction.

MTS' unique value proposition lies in the fact that it is a source of information for all potential users. Hospitals that consider improved health technology management an explicit goal will likely find value in the tool. The sheer amount of information required presents an opportunity to capture the additional benefits of regular and standardized data collection. Once fully validated, a tool such as MTS also has a fundamental role in translational research. For example, physicians and policymakers alike might be interested in relationships such as the impact of changes in technology policy, technician training, or equipment distribution on patient outcomes, productivity, or satisfaction. There are metrics available to describe many of these concepts, and MTS provides a mechanism for quantifying possible independent variables of interest.

## III. CHALLENGES

Cooperation among engineers, physicians, and policymakers is paramount to the success and usefulness of a tool such as the MTS. Construction of this metric requires extensive and up-to-date data that often cannot be obtained from records, if they exist.

Rather than seeing these challenges as obstacles that render the MTS impractical, they represent further points of action whose pursuit will strengthen the availability and accountability of health services. Through the expansive Priority Medical Devices Project, WHO has made available a wealth of information about and guidelines for the use of medical devices in certain types of facilities and even by health condition. UNICEF and other organizations have similar guidelines [10], and many ministries of health have developed or are currently developing their own standards. WHO also provides guidelines on inventory management [7]. There is plenty of guidance emerging. What remains is to take stock of national resources and begin to measure the true state of health services and equipment.

## IV. CONCLUSION

The current situation in developing countries is a one-way flow of technology down the wealth and development gradient. Indeed, the ultimate goal is to support local and regional industries that design equipment specifically for the developing world, and in particular for specific continents, regions and nations [6], [11]. International organizations such as Innovations in International Health (IIH) at the Massachusetts Institute of Technology have done much to promote and develop innovations for low-resource settings. Furthermore, medical professionals have begun taken matters into their own hands: Dr. O. A. Awojobi of Eruwa, Nigeria is the creator of innovative surgical tools fashioned partially or entirely out of locally available (and, notably, traditionally non-medical) items such as bicycle tires and motor jacks [12], [13].

A relevant question is whether ''high-tech'' equipment even has a place, or is appropriate, in low-resource settings. Appropriateness encapsulates ''effectiveness, safety, the ability of the community to pay for it, and the availability of expertise to utilize and maintain the technology'' [11]. Promoting the use of appropriate technology goes beyond adjusting the criteria for equipment procurement to building local design, manufacturing, and management capabilities on the ground. The MTS seeks to aid national health administrators in this final task by providing a single measure of adherence to national standards and progress in capacity-building.

The next step in MTS development is ensuring the feasibility of collection of the required data. The authors are currently undertaking this process at the sub-facility level in sub-Saharan Africa to demonstrate proof-of-concept. As part of the quantitative and qualitative validation process, the resultant scores will eventually be considered in the context of national guidelines on priorities in health (as available) and community perception of hospital capabilities in order to fuel a discussion of the construct validity of MTS. Sensitivity analysis will be performed using different functional forms of the MTS equations and different input values of the relevant variables. Based on these data, the authors will gauge the quantitative robustness of the MTS.

In the future, the MTS will also assist the development of patient-facing services that rely on accurate information about local health facilities. It is critical to simultaneously encourage adoption and modification by health administrators and planners according to their needs and to promote local innovation in order to build capacity, increase local procurement options, and ultimately improve the quality of equipment available for patient care.

## APPENDIX

See Chapter 2, Chapter 3, and Appendices B and C of Reference 1 for a more detailed explanation of the MTS, a sample calculation for 2 facilities in Nicaragua, and further discussion of the development of relevant variables.

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