Automated Medical Algorithms: Issues for Medical Errors

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Abstract. Medical errors can be reduced by the sharing of medical information and the correct application of medical information. A wealth of medical information exists in the form of published medical algorithms. These algorithms represent a summary of medical research ranging from simple calculations such as Body-Mass Index to complex outcome predictions. Application of such algorithms can generate information crucial to the clinical process. The barriers to their application include (among others): the lack of knowledge that they exist, uncertainty about their boundaries, difficulty in converting to the units expressed in the algorithm, and lack of availability at the point of care. Automation of medical algorithms can serve to both share the medical information as well as assist in the correct application of that information.

Medical Algorithms.

An algorithm is defined as “a step-by-step procedure for solving a problem or accomplishing some end especially by a computer”. The purpose of a medical algorithm is to improve the delivery of medical care. Figure 1 shows 16 types of algorithms that were encountered during the construction of a centralized repository of such algorithms. As can be seen from these descriptions, medical algorithms range from simple calculations such as determining the Body-Mass Index to complicated formulas for predicting clinical outcomes. Automated medical algorithms can help to reduce errors by ensuring proper selection and application of an algorithm. Some errors may be introduced as well, although these can be minimized through proper design and use of the system. Other authors have noted the value of medical algorithms in healthcare. In particular, McGinn et. al. note that validated clinical decision rules have “the potential to inform clinical judgment, to change clinical behavior, and to reduce unnecessary costs, while maintaining quality of care and patient satisfaction.” Other researchers have noted that “quantitative methods to

1. Coding & look-up tables
2. Comparison with normal population standards
3. Data conversion
4. Decision rules & triaging
5. Decision trees & flow diagrams
6. Diagnostic criteria
7. Diaries & symptom tracking
8. Functional state description
9. Grading and scaling
10. Probability & statistical analysis
11. Prognostic scores
12. Questionnaires
13. Risk determination
14. Simple classification
15. Simple formulas
16. Therapeutic indications & contraindications

Figure 1: Types of Medical Algorithms
enhance clinical judgment would be of tremendous benefit to physicians caring for the critically ill.” We believe that automation of medical algorithms can help to realize this potential.

Example.

We present here an example of the use of automated algorithms in clinical care. For maternal screening in obstetrics (AFP, estradiol, etc), laboratory results from analysis of a blood sample are used in combination with the gestational age to calculate the screening results. Often the obstetricians do not know an accurate date until an ultrasound is done, which may not happen until after the blood specimen is collected. An initial assessment of gestational age can be done using a calculating wheel (a circular slide rule for the 266 day gestation). The ultimate problem is that the method of date calculation needs to be documented since some methods are more accurate than others. Furthermore, the date wheel is easy to misapply. Using a couple of simple spreadsheets, the date calculations and screening results can be determined and filed along with the documentation of how the calculations were done. Improvements to the healthcare process have been made in several areas: 1) Misapplication of date wheel method is unlikely since the spreadsheet can do it accurately. 2) Communication has been improved because of the documentation of methods (which can be used for quality assurance). 3) The obstetrician has accurate data to use for patient care.

Not Using an Algorithm.

There are several sources of medical error or inefficiency that could be attributed to not using an algorithm.

Failure to use an algorithm when it would be appropriate to do so. When an algorithm exists and the clinician is not aware of it or considers it too cumbersome to apply, then important information may not be available for patient care. E.g. Clinicians are reluctant to calculate body surface area or anything that involves the use of an exponential or logarithm.

Failure to recognize or characterize different population and situations. An algorithm may prompt a clinician to recognize or characterize a situation differently. Without the algorithm, the clinician may be missing information that would improve patient care. E.g. A clinician is working with a condition for which there is an algorithm to calculate low risk versus high risk. A low risk patient might not need aggressive therapy and could avoid therapy-induced toxicities. A high risk patient might benefit from early and aggressive interventions.

Failure to risk adjust outcomes. It is important to take into account risk factors when comparing outcomes. Ignoring risk factors means that the comparison is done on different kinds of object (like comparing apples and oranges). For example, in infectious disease it is expected that a person exhibiting minimal pre-existing problems will have close to 100% survival while people with many problems and significant comorbidities will do poorly. By separating the patients into risk groups, outcomes can be compared within a hospital or between hospitals on the basis of their risk group.

Spending unnecessary money, wasting time. A clinician can waste considerable time and money by performing tests that generate no valuable information for their particular patient. Time and effort may also be wasted when re-inventing a reasoning process that is already embodied in a medical algorithm.

Potential Errors Using Algorithms.

Inappropriate use of output. An algorithm generates output that has to be interpreted by the clinician using it. If ambiguous words or meaningless numbers are the output, then they are likely to be misinterpreted.

Using a version out of date or with an error. Algorithms are constantly being revised and updated. Even a validated algorithm may be shown to be incorrect in a borderline population.

Using an algorithm irrelevant or unresponsive to condition. Once an algorithm exists for a particular condition, the tendency may be to try to use that algorithm for ALL related conditions. Another problem is that the algorithm may be applied appropriately, but the algorithm is simply not adequate. For example, McMurray et. al. found that the Oxford hip score (which was designed for total hip replacement) raised issues related to the lack of clarity of the algorithm, the coverage, and the ultimate validity of the algorithm.

Using an algorithm with inappropriate complexity. There are two types of inappropriate complexity. First, an overly simple algorithm may be used when a more complex one is called for. In contrast, an overly complex algorithm may be used where a simpler one will do. The biggest danger with this is that input data for the complex algorithm may be difficult, costly, or impossible to obtain.

Based on ambiguous data. Most people are familiar with the saying, “Garbage in, garbage out.” Ambiguous data can lead a clinician to input the wrong information. For example, if an algorithm
wants as input a value categorized as “high” or “low” and

Failure to properly specify the appropriate population or group. In particular, if there is a subpopulation that is of interest it is important not to confuse the subpopulation with the population. For example, if a clinician is working with the prevalence of a genetic carrier state in a general population versus a high risk subpopulation and then wants to discuss penetrance in patients who are carriers (number of people who are carriers who develop the disease), it is easy to confuse the two populations and this affects the rate calculations.

Problems with Typical Algorithm Representations

Typical algorithm representations are paper questionnaires or checklists. They tend to be generated such that only one form is necessary and this often leads to either an over simplification of the algorithm, or a cumbersome form with lots of choice points. To reduce the time necessary for application, the calculations are usually kept simple and the hope is often that a person will no longer need the form, but will remember the algorithm and apply it properly. paper-based and often simply represented. The paper forms seldom include supporting documentation (such as a reference to the original source of the algorithm), and frequently the assumptions made about the patient population are not specified. This is a particular problem for people who are new and/or untrained in the use of the algorithm.

Error Reduction by Automation

Reduce data entry errors. There are two ways that automation can reduce data entry errors. The first is to link the algorithm directly to the patient data through an interface with an electronic medical record. This can result in the fewest errors if the electronic medical record is well-verified. A second way to reduce data entry errors is to create an interface that checks for the reasonableness of the data coming into the system. For example, entering a body temperature over 110F could generate a warning message. There are numerous other techniques related to interface design for collecting good data that can be employed. 8,9

Remove calculation errors. This is one of the easiest error reductions to achieve. A computer can do even complicated calculations quite well. Once the system has been shown to reliably calculate the algorithm (has been tested thoroughly), then accurate calculations can be ensured.

Incorrect recall of algorithm details. A computer does not forget; therefore, every time it applies an algorithm it knows all of the details. This is one of those things that computers are good at doing and that complements a person’s capabilities.

Selection of overly simple algorithm. The computer has no trouble applying complex algorithms. When a clinician selects an algorithm, the computer can suggest that alternative algorithms exist. If the algorithm is fully hooked to the data system, it may even be able to determine whether all of the data needed is present.

Selection of wrong algorithm for population or situation. The computer representation includes all of the constraints and assumptions. Some of these may be checked automatically against data in the system. Some can be asked through questions at the front of the algorithm (e.g. Is your patient female? Answer: no. Response: This algorithm is only valid for women, please see xxx for the correct algorithm.) Finally, even without asking the questions, a description of the assumptions and constraints can be presented first as a set of information to be checked by the clinician before applying the algorithm.

Inappropriate use of output. Automated algorithms can provide not only the calculation capability, but can also provide the reference to the interpretation of the output. This reference will help to ensure that the output is used in an appropriate manner.

Using a version out of date or with an error. An automated system can check a centralized server to see if there are any updates to the algorithm. An internet connection may be necessary for this to occur. As in many software packages, an automatic process can run whenever the program is started and a connection is available to see if there are any updates. As for an erroneous calculation, there should be rigorous testing of the algorithm before it is made available to ensure that it reliably performs the calculations documented in the algorithm.

Validation of Algorithms.

There still remains the issue of whether to believe an algorithm or not. For this issue, it is extremely important to document the source of the algorithm as well as any validation studies of the algorithm. In the area of medical algorithms called Clinical Decision Rules (CDRs), there has been some effort to describe standards for both the derivation and use of such rules. 5 McGinn et. al. list 4 levels of confidence ranging from rules that need further evaluation (level 4) to rules that can be used in a wide variety of settings (level 1). The levels are determined by the
types of validation that have been performed (e.g. narrow prospective sample, impact analysis, etc.).

MEDAL – MEDical ALgorithms project.

The goal of the Medical Al gorithms Project is to provide a collection of algorithms in a format that supports clinicians, programmers, and validators. \(^4\)\(^{10}\) It contains a collection of over 2,650 algorithms represented in a spreadsheet format with references to the original sources. MEDAL uses a standardized representation of the algorithms that was designed to support future automation. In particular, the algorithm is represented as: a) overview and reference to documentation, b) unit conversion, c) entry of data, d) intermediate calculations, e) interpretation, f) data tables. Each spreadsheet is write-protected except in the data entry areas so that the algorithms can be reliably calculated. However, if a modification in the algorithm is desired by the user, it is possible to obtain the password to unlock the sheets. This enables further development of algorithms, perhaps to include new fields and formulas based on ongoing research.

Conclusion and Future Work.

It is clear that medical algorithms are one key format for sharing medically relevant information and that the sharing of such information is needed for safe patient care. We have described here a number of errors that can be minimized through the use of automated medical algorithms. We have also described ways in which potential introduction of errors by such automation can be minimized, primarily through rich communication of algorithm details and validation. Since the ultimate responsibility for proper use resides with the clinician, there is a great need for such a complete representation of the algorithms, enabling easy retrieval of relevant information.

References

Background

The National Patient Safety Foundation has sponsored a report to describe the current research being pursued in the area of medical error reduction and to identify the gaps in this effort. A total of 23 gaps were identified—among them was a need for more research in the area of communication and information sharing. One of the areas that we see a need to explore is the wealth of published information in the form of medical algorithms. Centralizing and automating medical algorithms is one way to share information among a wide range of clinical care providers. Furthermore, automation of medical algorithms assists in the correct selection (reducing errors of planning) and application of that information (reducing errors of execution).

Medical Algorithms

The purpose of a medical algorithm is to improve the delivery of medical care. A previous effort revealed 16 types of algorithms that were encountered during the construction of a centralized repository of such algorithms ranging from simple calculations such as determining Body-Mass Index to complicated formulas predicting clinical outcomes.

Medical Algorithm Issues

Issued we have identified include: 1) Not Using an Algorithm which can be further characterized as causing the following errors or inefficiencies: a) Failure to use an algorithm when it would be appropriate to do so. b) Failure to recognize or characterize different population and situations. c) Failure to risk adjust outcomes. d) Spending unnecessary money, wasting time. 2) The second issue is Potential Errors Using Algorithms which are characterized as: a) Inappropriate use of output. b) Using a version out of date or with an error. c) Using an algorithm irrelevant or unresponsive to condition. d) Using an algorithm with inappropriate complexity. e) Using an algorithm based on ambiguous data. f) Failure to properly specify the appropriate population or group. 3) The third area is Problems with Typical Algorithm Representations which include: a) Oversimplification of algorithms to enable questionnaire or checklist formats, or cumbersome forms with lots of choice points. b) Calculations are often simplified to reduce calculation time. c) Supporting documentation is often not available. d) Assumptions about patient population are often unspecified.

Error Reduction by Automation

The following are potential benefits of automation: a) Reduce data entry errors. b) Remove calculation errors. c) Facilitate recall of algorithm details. d) Reduce selection of overly simple algorithm. e) Reduce selection of wrong algorithm for population or situation. f) Guide appropriate use of output. g) Prevent use of a version out of date or with an error.
Validation of Algorithms

This is an extremely important issue which we lack the space to describe.

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Conclusion and Future Work

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References