Implementation of a Mortality Prediction Tool
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Executive Summary:

We have been charged with the implementation of a Mortality Prediction Tool developed by the Duke Institute for Health Innovation that identifies patients at high risk of in-hospital death. The goals of implementation are to improve overall goal-concordant care for patients, while also reducing inpatient mortality. The tool has already been implemented on the Hospital Medicine services, and we outline the methodology and logistics associated with its current use. The risks and alternatives associated with the rollout and implementation of this tool are reviewed with special emphasis on rationale and metrics of success. We also make recommendations for advancing this tool into the oncology services who care for a group of patients at especially high-risk for inpatient mortality.

Background:

Approximately 2% of patients admitted to American hospitals die during their inpatient admission. Efforts to reduce preventable in-hospital mortality have focused on improving treatments and care delivery, and efforts to reduce non-preventable mortality have focused on supporting patient preferences to die at home and attempting to reduce health care costs in the inpatient setting (i.e. hospice programs). Early identification of patients at high risk of in-hospital mortality may improve clinical and operational decision-making and, more importantly, improve outcomes for patients.

Recently, experience with a machine-learning model developed at Duke was published in JAMA Open Network. The primary aim of this study was to prospectively and externally validate a machine learning model that predicts in-hospital mortality at the time of hospital admission for adult patients based on readily available data in the electronic health record. The authors found that their model’s performance prospectively almost exactly matched its performance retrospectively across two different cohorts, and the results were then externally validated separately from the training datasets.

Reducing mortality in our inpatient population is an important issue as we optimize the quality of our patient care and focus on improving our US News and World Report ranking. As part of this effort, the Duke Institute for Health Innovation recently developed and validated the aforementioned mortality prediction model. The next steps are to decide where this model should be piloted, and design the clinical workflows for implementation.

Our Duke Clinical Leadership Program (DCLP) team reviewed mortality data for the institution, learned how the data are generated, and also evaluated the data for locations and specialties that are drivers of our mortality index. We then reviewed the development of the mortality prediction model and the components that determine the score. Using this knowledge, our goal was to design a proposed process for the implementation of this model by determining: (1) who will
receive the model output(s) (clinicians vs. RNs, for example), (2) how often the information will be reviewed, and (3) what other data and information will be incorporated to support decision-making. Workflow design should also include working with clinical teams to decide what appropriate interventions, actions, and escalations could be based on this model. Ideally, the implementation will be customized for various clinical service lines to ensure alignment with existing workflows and patient care needs, which may differ in the local contexts of particular units and/or service lines. Lastly, we aimed to design and propose a method for measuring the clinical utility and effectiveness of the model, and the interventions that result from its clinical use.

**Methods:**

The Mortality prediction tool is a machine learning model developed to predict in-hospital death. It was integrated into the EHR to support the clinical care of patients at high risk for in-hospital mortality. Over time, the model is able to determine what data inputs are more important in prediction of mortality and adjust predictions accordingly. Some of the data that this tool incorporates are demographics, vital signs, laboratory values and medication administrations.

To date, this tool has already been implemented for patients admitted through the emergency department to both the teaching and non-teaching Hospital Medicine services, and exclusively uses data from the current hospital encounter. The data are pulled from the EHR each night at midnight, and used to calculate the risk of in-hospital death for every patient admitted that day. A nurse then reviews the high and medium risk patients identified by the algorithm, and notifies the responsible clinician. The current dashboard pulls data from the prior 24 hours, and on average identifies 6-10 patients per week for further attention/intervention. An e-mail is then sent the inpatient attending (Appendix B), and the patient is prioritized for additional services, including more targeted involvement of case management, or to help decide on appropriateness of a goals of care conversation. A dotphrase (.gmacp – Appendix C) is available to help guide that conversation and documentation thereof, while also decreasing variability and standardizing the clinical workflow. In this Hospital Medicine implementation, the mortality prediction model is intended to be an additional resource in the context of other factors including clinical judgement, social situation of the patient, etc. This model does not take into account any expected treatment effects.

As a DCLP team, we met with the developers and users of this tool on multiple occasions, and met with each of the key stakeholders and subject matter experts involved. This is a complex informational tool that was described to our team in great detail. We then collaborated with Yvonne Acker, the lead of the implementation team, to learn how the tool was used in the hospital as outlined above, and to understand the outcomes of that implementation to date. She and her colleagues on that project team provided constructive feedback regarding barriers to implementation. From these discussions, and using our own clinical expertise, we developed
recommendations for the future use and implementation of this tool in other Duke contexts, taking into account the climate of the current COVID-19 pandemic.

**Risks and Alternatives:**

The Mortality Prediction Tool is intended to identify patients at high risk of in-hospital death, so that this population may be especially targeted for higher-level interventions. Ideally, these interventions would lead to patients receiving the most appropriate care near the end of life enabling death with dignity in the most appropriate location (so-called “goal-concordant care”).

**Our goal is to ensure that patients understand their prognosis, and that we understand their overall wishes and goals of medical treatment.**

To the contrary, a major risk for failure lies in a rankings- and reputation-based rationale for implementing this tool. Over a 7 year period, Duke has steadily fallen from a high of #8 on the US News Best Hospitals Honor Roll, to now no longer being in the top 20. Given the very problematic and nebulous nature of rankings formulas, we must be careful not to aim our intervention at improving rankings.

As Dr. Bae outlined eloquently in his recent letter to JAMA,

> “Conflicting information may lead hospitals and health systems to misdirect resources toward improving rankings on a particular measure and potentially miss opportunities to improve health and health care delivery. Furthermore, the visibility of hospital ranking and the desire to achieve and promote a high ranking is consumer facing advertisements may prompt hospitals to invest in strategies to improve their rankings whether or not those strategies improve care delivery and outcomes.”

Instead, we have made it clear that our focus in this proposed implementation plan below is on fostering and facilitating prognostic awareness, and truly goal-concordant care among patients at high risk for death in the hospital. To ensure this, we must consider who receives the data, how clinicians and ancillary staff are evaluated on their use of the data, and what overall metrics are used to gauge effectiveness of this tool.

Once past the rationale and roll-out of the tool, we focused on the risks associated with the model itself. It may lead clinicians to over- or under-estimate a patient’s risk of inpatient death, or to more blindly focus on goals-of-care discussions only among those patients identified as “at risk” by the tool. Underestimation of risk may result in a patient not receiving necessary treatment, or delays in care. Overestimation of risk may result in inappropriate de-escalation of care for those who might have otherwise had positive and goal-concordant outcomes. This may be mitigated through ongoing education regarding the tool, and careful selection of the metrics used to judge its success (and that of its end users).
Alternative plans could include the following: (1) no change to current care delivery, (2) more general efforts to increasing awareness and education around mortality prediction, (3) more active engagement of palliative care for hospitalized patients, teams in a less targeted fashion, or (4) simply requiring a note discussing advance care planning for all admitted patients. Of note, full-scale implementation of this tool is limited by competing priorities of COVID-19. There are well-described challenges to having end of life conversations with patients, families and caregivers while visitor restrictions are in place, and face to face meetings are limited.

**Recommendations:**

We recommend targeting the 9100 hematologic malignancies unit for the next mortality prediction tool implementation. This is a high-risk group for inpatient mortality, and a clinical area wherein the tool is not yet implemented. This recommendation is driven by several key considerations, including: (1) the unit’s relatively long average length of stay, (2) its high likelihood of inpatient mortality and/or death within 30 days of discharge, (3) the wide variation in prognosis among its patient population, (4) the fact that many of its patients are receiving risky but curative-intent therapies that themselves are associated with a high rate of serious complications, (5) its staffing by a relatively smaller and close-knit faculty, most of whom round frequently throughout the year, and (6) the recognition that this is a unit where there has been very little involvement of palliative care clinicians historically.

We are aware that the 9100 unit has been identified as an area with high observed-to-expected mortality and targeted for clinical documentation specialist interventions to enhance appropriate and complete documentation of illness severity. Implementation of the mortality prediction tool in this setting could further enhance the ability of the documentation specialists to target higher-risk patients, wherein current documentation may be inadequate. In addition, Dr. LeBlanc already serves as the 9100 unit’s representative to the inpatient mortality review process, led by Dr. Jon Bae and Yvonne Acker, and thus could facilitate and message this implementation as an insider within the group, enhancing the likelihood of success.

Alternative adult oncology inpatient services of interest for this implementation include: (1) solid tumor oncology, (2) stem cell transplantation, (3) gynecologic oncology, and (4) surgical oncology. Further driving our recommendation to proceed with the 9100 unit implementation are the following considerations: (1) the solid tumor oncology service already has an integrated palliative care co-rounding initiative in place, and Dr. Yousuf Zafar is already planning an implementation of the mortality prediction tool in the near future; (2) the stem cell transplantation unit features patients who, by definition, have a 5-25% 100 day mortality rate from transplant, thus the prediction tool would likely identify nearly all patients as high-risk, and/or require further development and validation to be more useful in a targeted implementation; in addition, there is an ongoing randomized clinical trial of integrated palliative
care at time of transplant admission, which is most likely a more effective way to impact the issue at hand, given the markedly positive outcomes seen in a single-site trial of this same palliative care intervention; (3) the gynecologic oncology unit has already devised and implemented its own high-risk model of care, to facilitate and document advance care planning and goals of care discussions among patients with a high likelihood of cancer related mortality; lastly, (4) surgical oncology is a smaller and more diverse service, and there is concern that the mortality prediction model may not be sufficiently validated for application within a primarily surgical population.

Based on learnings from the current mortality prediction tool implementation on the general medicine services, as well as knowledge about the inner workings of the 9100 service acquired from key stakeholders, we recommend the following initial implementation approach outlined in Appendix D.

Following the roadmap described in Appendix D would foster the ability of Duke Health to provide the most high-quality, safe, effective, and goal-concordant care possible to our patients and families facing a blood cancer diagnosis, consistent with our overall institutional strategic plan to “lead in the delivery of the highest-quality, patient centered care.”

**Next Steps and Key Elements for Success:**

A key element to handoff to next year’s team is to consult with inpatient oncology units for implementation and expand utilization of tool. More data and machine learning will provide a robust data set for analysis and refinement of the tool within an expanded population.
Appendix A: Current Process for Implementation of Mortality Risk Index

1. Adult patients admitted to Hospital Med from ED
2. Nightly data extraction from EHR with mortality risk calculated
3. Nurse reviews list, prioritizes patients and notifies provider of risk
4. Hospital Med Teams discuss need for advanced care planning
6. Next steps: Expand to other service lines
Appendix B: Sample E-mail Notification of Advance Care Planning Need

Subject: Patient Notification - Hospital Medicine Advance Care Planning QI Project

To: XXX

Your patient, XXX (MRN: XXX), who was admitted on XX/XX/20 has been identified as potentially benefitting from Advance Care Planning. Please consider a Goals of Care discussion during this admission using the .gmacp dot-phrase. (Note: Completed Advance Care Planning can be billable) *If you believe the patient is not appropriate for Advance Care Planning, reply to this e-mail indicating why Advance Care Planning was not provided so we can better understand potential obstacles.*

If the patient is appropriate for Advance Care Planning, **Pharmacy** will provide medication reconciliation at discharge (similar to the current process used with high risk re-admission patients). Please page Pharmacy to review DC med rec between 0700-1430 when orders are pended (“save work” button). For questions, please page 970-7100.

**Case Management** will be doing their usual assessment and will determine if any additional discharge resources are indicated. They are also available to participate with the provider in any Advance Care Planning discussions that are being had with the patient and/or family. For patients being discharged to our community partners and facilities (e.g. home health, skilled nursing facility or hospice), the Case Manager will include the Advance Care Planning note in the information that is sent to the organization/facility.

In addition, a **Clinical Documentation Improvement (CDI)** nurse will be closely reviewing the chart to make sure documentation is accurately reflecting the patient’s current medical condition and co-morbidities. Please respond to any posed queries as soon as possible or contact the CDI reviewer if documentation clarification requests are unclear.

The goal of this project is to improve the quality of care for this at-risk patient population and to ensure each patient’s wishes are documented appropriately for future care.

Thank you for providing this valuable service for our patients.
Appendix C: Advance Care Planning Note Template

@ACPBEGIN@

Discussion held with: (Drop down: 1) Patient 2) Patient and Family 3) Other(HCOPA, Next of Kin, Guardian) as patient unable to participate in conversation due to ***. All parties involved voluntarily partook in the conversation.

@M@@LNAME@ is currently hospitalized for ***. @HIS@ current clinical status is ***.

Discussion:

@M@@LNAME@ demonstrates/does not demonstrate a proper understanding of his condition and comorbidities.

At this time, @M@@LNAME@ indicated to me that @HIS@ most important goals include the following: {Goals of care:36800} (this is a dropdown already in another dotphrase we can utilize).

@M@@LNAME@ has expressed that @HIS@ biggest concerns at this time include: ***. (examples: comfort, pain, quality of life, destination outside of hospital)

@M@@LNAME@ explained to me that the life skills or abilities that @HE@ currently values the most include: {Life skills you wish to preserve:36802} (this is a dropdown already created in another dotphrase we can utilize).

In the event of cardiorespiratory arrest @HE@ reports that he would/would not want resuscitation including CPR, defibrillation, mechanical ventilation, or medication support/pressors.

@M@@LNAME@ indicated to me that @HE@ {has has not:20194} shared @HIS@ wishes for @HIS@ future care with @HIS@ family.

@M@@LNAME@ reports that @HE@ believes that @HIS@ family understands @HIS@ wishes.

@M@@LNAME@ indicates that if @HE@ was unable to speak for himself that he would choose *** as his surrogate decision maker.

Time In: ***
Time Out: ***
Total Face-to-Face Time Discussing Advanced Care Planning: *** Minutes

***

@ACPEND@
**Appendix D: Proposed New Site and Implementation Process**

**We recommend the following initial implementation approach:**

1. Activate the mortality prediction tool for all patients admitted to the 9100 service, using the method currently used for general medicine (overnight data run, identification of high-risk patients each morning, review by team lead, then messages sent to key parties).

2. On the 9100 unit, the following key stakeholders should be part of the notification process for high-risk patients:
   a. The attending of record for that patient
   b. The intern or NP/PA who is responsible for the patient’s care that week
   c. The nurse manager of the unit, Joey Misuraca
   d. The patient resource manager of the unit, Michael “Paul” Brown
   e. The pharmacy team (or team lead/designee)
   f. Clinical documentation specialists (such as Sarah Simone or equivalent)
   g. A palliative care clinician designee, to participate in discussions about these patients’ needs, possibly even as part of the inpatient rounding team should staffing allow. This could create the opportunity to more specifically examine unique barriers to high-quality palliative and end-of-life care for patients with blood cancers at Duke, which are extensively documented in published literature, including the lack of availability of palliative blood transfusions for those enrolling in hospice care, which drives many patients and families to either not enroll in hospice at all, or to do so very late in their course of illness. The evolving “bridge program” in Duke Homecare and Hospice could be a partial solution, if they have a seat at the interdisciplinary team table when discussing care plans for the hematologic malignancy population.

3. Develop and implement guidance, and expectations, for what could/should be done for those patients who are identified as being high risk for inpatient mortality. This must involve participation and discussion amongst the faculty and staff of the 9100 unit. Possibilities include:
   a. Development and use of a dotphrase that describes the patient’s at risk status, and facilitates documentation of the ensuing discussion of this risk, including but not limited to overall goals of care, expectations/prognosis, and code status
   b. Consideration of a palliative care consultation. This recommendation builds upon data from a recent randomized study done at Duke, and 3 other sites, showing that integration of palliative care during intensive induction therapy for patients with acute myeloid leukemia increases the likelihood of discussing end-of-life care preferences, and reduces the likelihood of providing chemotherapy in the last 2 weeks of life, while also improving overall quality of life and reducing anxiety, depression, and post-traumatic stress.
c. Triggering formal documentation review and feedback for each and every high-risk patient

d. Implementation of a specific high-risk discharge process/checklist, to be followed by the patient resource manager (will require development by the team)

e. Implementation of a specific high-risk pharmacy process for medication review/reconciliation at discharge (will require development by the team)

It is essential to the successful implementation of this model that it be accompanied by an evaluation schema, and outcomes assessment plan. We recommend the following:

1. After a trial period, conduct periodic assessments of the prediction tool’s accuracy at identifying patients who ultimately died in the hospital, or within 30 days thereafter

2. Conduct period manual review of documentation changes that may have resulted from this implementation

3. Review and discuss key stakeholders’ experiences with the tool, and obtain feedback about how to improve the implementation

4. Development and dissemination of a “report card” schema, for reporting both at the unit level and the attending level, the overall adherence to the recommended/required actions outlined above. This then becomes a measure of implementation success and also a way to identify those team members in need of additional training/mentorship/support to enhance their practice.