STROKE TRANSPORT MAPPING WHITE PAPER

DESTINE HEALTH

Smarter Stroke Decisions

PREPARED BY

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EVIDENCE BASED PRE-HOSPITAL TRANSPORT AS A POWERFUL, FAST, AND EFFECTIVE WAY TO IMPROVE OUTCOMES FOR STROKE PATIENTS

Definitions

- Ischemic stroke: loss of blood flow to the brain due to a blockage in an artery supplying the brain with blood
- Large vessel occlusion: the blockage is occurring is one of the major large arteries feeding the brain
- Alteplase: intravenous "clot-busting" medication designed to dissolve the offending clot and restore blood flow to the brain
- Endovascular therapy (EVT): minimally invasive procedure where the offending clot is physically removed from the artery so blood flow can be restored
- Can only be offered to patients with large vessel occlusions (as the devices cannot currently reach the smaller arteries in the brain)
- Thrombolysis centre: a hospital which can provide treatment with intravenous alteplase 24/7/365 either by onsite neurology expertise or telemedicine.
- EVT centre: a hospital which can provide both intravenous alteplase and is staffed and equipped to perform EVT 24/7/365

Problem

In 2015, the breakthrough of endovascular therapy (EVT) revolutionized ischemic stroke treatment. Access to EVT became the new standard of care for eligible patients with large vessel occlusion strokes. Ischemic stroke can also be treated with alteplase (and guideline based care recommends administering both treatments to eligible patients).(1,2) Both treatments are highly time sensitive – the faster they are administered, the more likely it is that the patient will have a good outcome.(3-5)

Due to the experience, equipment, and expertise needed to offer EVT it is not practical to make EVT available at all hospitals. As such, health systems have centralized its location to urban tertiary hospitals, much like the centralization of advanced trauma or cardiac care. This leaves other smaller outlying hospitals only offering alteplase to ischemic stroke patients. In many health systems, referral patterns have been established where patients are taken to their nearest hospital (often one that does not offer EVT) for treatment with alteplase and then if eligible transferred to a centre which offers EVT. This has been termed "drip and ship" transport.

Problem Cont.

This system has the advantages of having short initial transport meaning patients are seen in a hospital sooner. Additionally, this allows for patients to be spread more evenly over the health system and not overcrowding one hospital. However, this system can cause significant delays in access to EVT for patients especially if the community hospital is inefficient and takes a long time to administer alteplase and then prepare the patient for transfer.(6,7)

Another source of inefficiency often arising in urban areas is that the thrombolysis centre may be very close in proximity to the EVT centre, begging the question at what point should be patient just be taken directly to the EVT centre in the first place?

Is it better for patients to receive alteplase early by going to hospital that only offers this treatment first and then be transferred to a tertiary centre for (delayed) EVT? Or is it better to delay alteplase and receive earlier access to EVT by going directly to the hospital that provides both alteplase and EVT?

Solution

Sophisticated modelling work has shown that under certain conditions it is in the patient's best interest to bypass their closest thrombolysis only hospital and be taken directly to an EVT centre (termed "mothership" transport).8-10 Unfortunately, there is no one size fits all solution to when bypass is appropriate – it is not as simple as drawing a time radius around the EVT centre.

There are several different factors that influence which transport option is best for the patient. The most important being the time from stroke onset to treatment (with both alteplase and EVT). Time from stroke onset to treatment in drip and ship transport is made up from the following components:

- Time from stroke onset to 911 being activated
- Ambulance response time and time spent on scene with the patient
- Travel time to the nearest thrombolysis centre
- Time from arrival at the thrombolysis centre to the administration of alteplase (termed door to needle time)
- Time from thrombolysis administration to departure for the EVT centre (this added to the door to needle time is termed the door in door out time)
- Travel time to the EVT centre
- Time from arrival at the EVT centre to start of the EVT procedure (termed door to puncture time)
- Travel time to the EVT centre
- Time from arrival at the EVT centre to start of the EVT procedure (termed door to puncture time)

Solution Cont.

Time from stroke onset to treatment in mothership transport is made up of the following factors:

- Time from stroke onset to 911 being activated
- Ambulance response time and time spent on scene with the patient
- Travel time to the EVT centre
- Time from arrival at the EVT centre to administration of alteplase (door to needle time) and to the start of the EVT procedure (door to puncture time)

The relationship between these different times is illustrated in Figure 1.

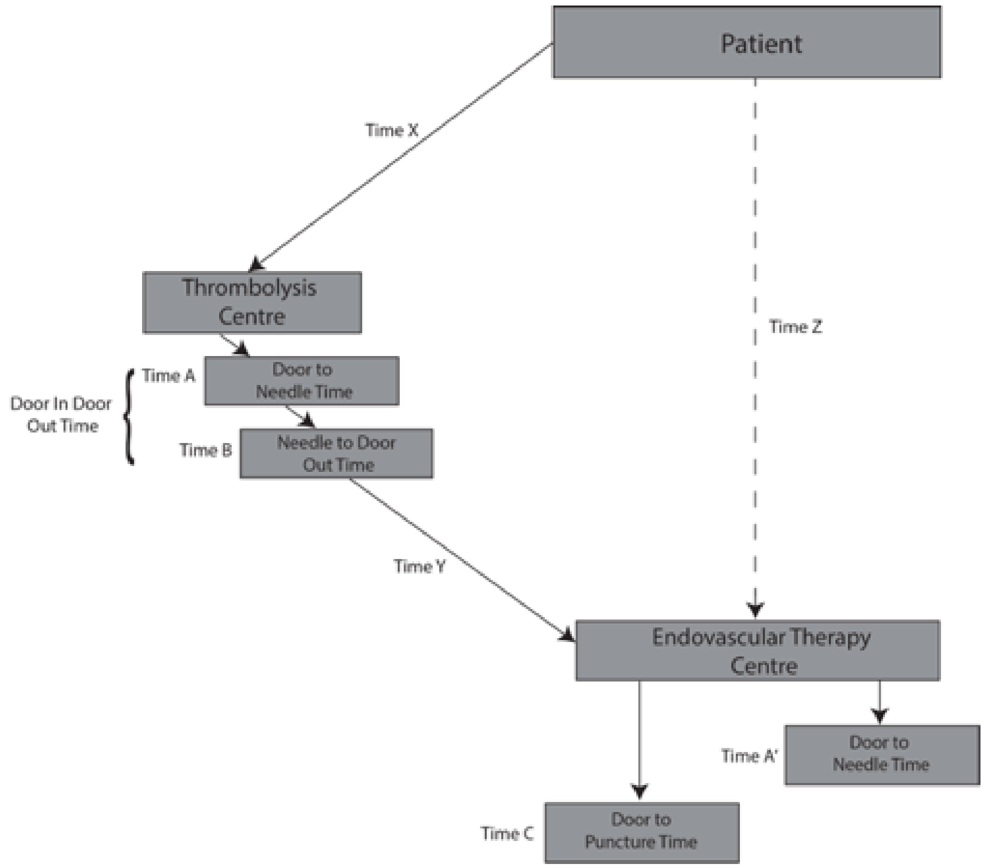

Figure 1. Diagram indicating the transport and treatment times involved in drip and ship (solid line) and mothership (dashed line) transport. Time X indicates the travel time from the patient to the thrombolysis centre, Time Y indicates the travel time from the thrombolysis centre to the endovascular therapy centre, and Time Z indicates the travel time from the patient to the endovascular therapy centre. Time A indicates the door to needle time at the thrombolysis centre, Time A' indicates the door to needle time at the endovascular therapy centre, Time B indicates the time from alteplase administration to departure for the endovascular therapy centre (Time A + Time B = door in door out time), and Time C indicates the door to puncture time at the endovascular therapy centre.

Solution Cont.

While there are many moving parts in thinking about time from onset to treatment it really boils down to two different factors: how far from the hospital(s) is the patient, and how fast are the hospital(s) at delivering treatment?

The other factor to consider is the likely diagnosis of the patient at hand. Brain imaging is needed to confirm the diagnosis of ischemic stroke. As this is not available in the field (apart from the few mobile stroke units currently operating) the diagnosis made in the field is a probabilistic one. Using the patient's symptoms and one of many stroke severity scores, a determination is made as to whether it is likely that the patient is experiencing an ischemic stroke with LVO.

However, these scores are not perfect. Depending on the score used, anywhere from 15-55% of patients screening positive may actually be experiencing a stroke due to LVO.11 The remaining patients may be experiencing an ischemic stroke without LVO (small ischemic stroke), a hemorrhagic stroke, or one of many other conditions with symptoms which mimic a stroke (ex. a seizure or migraine). Considering the potential diagnoses and the proportion at which they occur for patients screening positive for LVO in the field is very important as it impacts the transport decision which will predict best patient outcomes.

While patients with stroke mimicking conditions do need care, typically this care is not time sensitive and the patient often will have a good outcome.(12-16) Patients with hemorrhagic stroke need high level care and often experience poor outcomes from their stroke; however, there is currently no evidence that this care is time sensitive in the same way that it is for ischemic stroke.(17-21) As such these two patient groups are less important in determining the best predicted transport option than patients with ischemic stroke.

Patients with small ischemic strokes need immediate alteplase. In most scenarios, the fastest way to access alteplase is transporting the patient to their nearest hospital. Unless the patient's closest hospital is an EVT centre this means the drip and ship method will provide the fastest access to alteplase and as such predict best outcomes in this patient group. For patients with LVO the choice is not so simple, a careful balancing act between quick alteplase and delayed EVT (drip and ship) or delayed alteplase but quicker EVT (mothership) must be considered (Figure 2).

This means that for transport decision making, if the population of patients being screened for stroke contains more patients with small ischemic strokes per every patient with an LVO the best transport decision for the population will involve more drip and ship utilization. The reverse is also true, the better the stroke severity scale is at identifying ischemic stroke due to LVO (more LVO patients per every small ischemic stroke patient) the more the best transport decision for the population will involve mothership utilization.

Solution Cont.

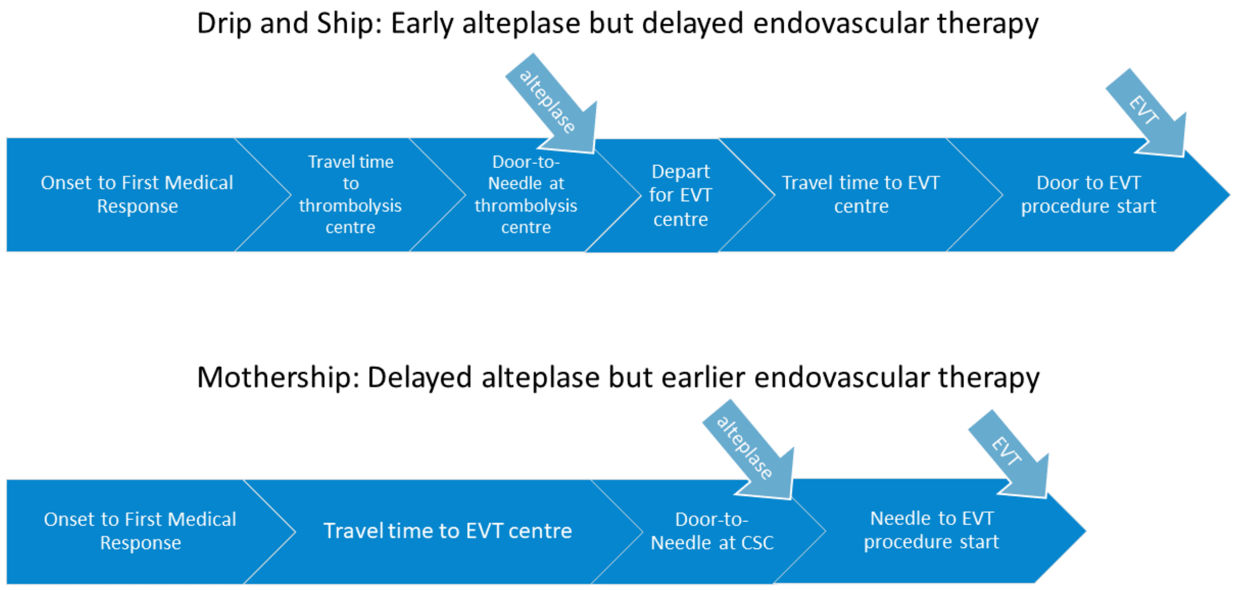

Figure 2. Diagram displaying the treatment time tradeoff involved in drip and ship versus mothership transport. Drip and ship results in early access to alteplase but delayed access to EVT whereas mothership results in delayed access to alteplase but earlier access to EVT.

However, mothership is not always the right answer, even in a population consisting of 100% patients with LVO.9,10 For these, even though EVT is far more effective than alteplase; (22-26) alteplase is not ineffective.(27) Treatment with both alteplase and EVT are highly time sensitive.(4,5,27)

This complex interplay between the declining probability of good outcome as time from onset to treatment increases, the factors that increase the time from onset to treatment, and the likely distribution of diagnoses of the population of patients screening positive on a stroke severity screening tool has been modelled by a group of scientists and physicians from the Calgary Stroke Program.8 The models, when combined with a region's specific geography, drive times to and between hospitals, and health system variables, can be used to predict the probability of good outcome (defined as being functionally independent at 90 days after stroke) for both the drip and ship and mothership transport. In this way it can be determined which one is predicted as best for patients and he results can be visualized on a map such as the example on the following page.

Solution Cont.

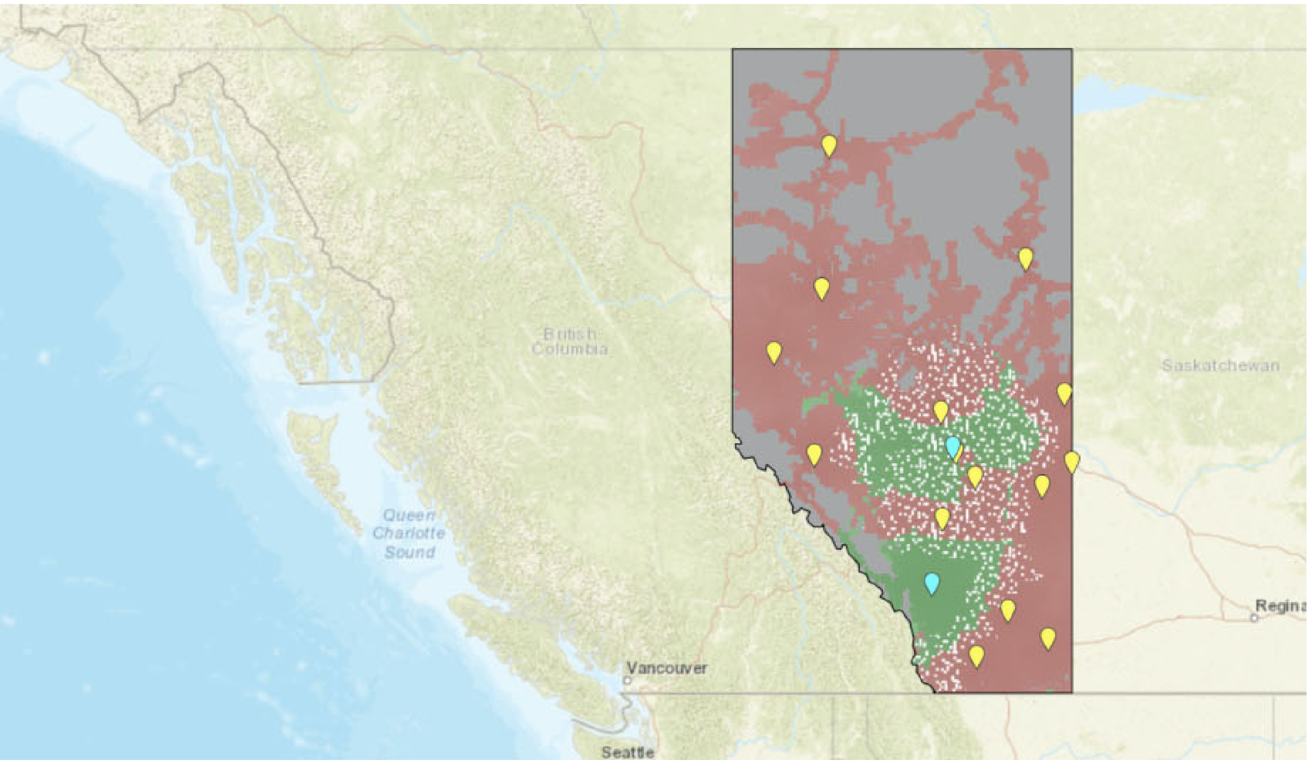

Figure 3. Map of Alberta, Canada displaying the best predicted transport option for patientsscreening positive for large vessel occlusion stroke using the Los Angeles Motor Scalescore. Yellow pins indicate the location of thrombolysis centres, blue pins indicate thelocation of EVT centres. Red areas indicate that drip and ship predicts best outcomes forpatients, green areas indicate that mothership predicts best outcomes for patients. Areasoverlaid with white dots indicate that the difference in probability of good outcomebetween drip and ship and mothership is less than 0.01.

Creating Maps for any Region

While the interplay between geography, system efficiency, likely patient diagnosis, and the best predicted transport option is complex – applying this modelling knowledge to your health system doesn't have to be. DESTINE Health Inc. has created an interactive decision support tool, DESTINE stroke, which takes these models and applies their results to your unique geography.

The decision support tool is accessible online via www.destinehealth.com; users are supplied with custom log-in information which allows them to access their health region and all stroke hospitals it contains. Below is an example of what would be shown for a user in Alberta, Canada.

Creating Maps for any Region Cont.

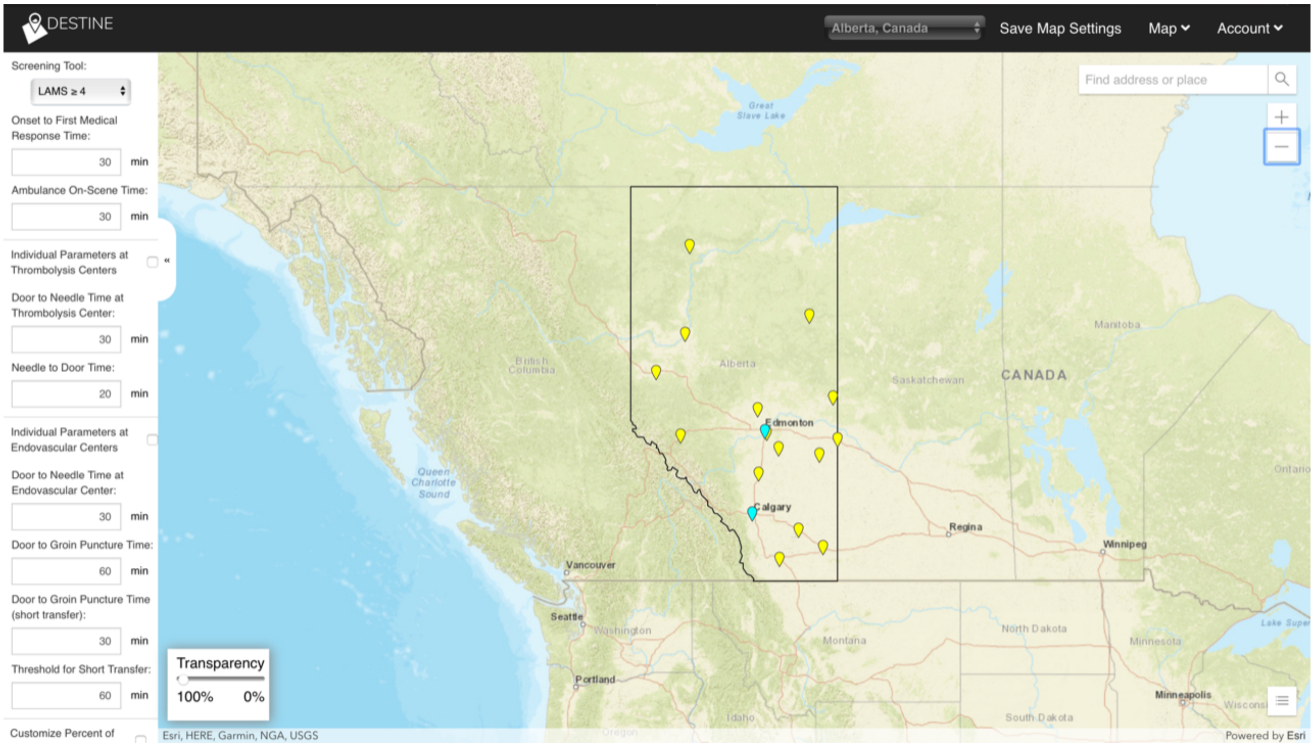

Figure 4. User view for a user in Alberta, Canada. All stroke centres in Alberta are shown using pin points, blue pins represent EVT centres and yellow pins represent thrombolysis centres.

The user has the ability to customize the screening tool used by EMS personnel in the field (the LAMS tool is shown in this example) as well as hospital level factors such as the hospital's door to needle time or door to puncture time. These parameters can be customized on a system wide level or an individual hospital level.

The user has the ability to customize the software to reflect workflow in their health system. Treatment times, including the door to needle time, door in door out time, and door to puncture time can be customized by the user. The user can customize these parameters on a system wide level or drill down to the individual hospital level and enter each hospital's specific treatment time values. Other system level parameters which can be considered are: the proportion of patients treated with alteplase and/or EVT, whether expedited door to puncture workflow can take place for transferred patients, and pre-hospital work flow parameters.

Creating Maps for any Region Cont.

Finally, the user has the ability to choose one of several built-in (or add a custom) field screening tool used by EMS personnel to identify patients with potential LVO in the field. Once these parameters are set the user can generate their own custom colour coded transport map similar to that shown below. Within the software, the modelling work described above, the parameters entered by the user, as well as drive times to and between hospitals [generated by ArcGIS (Esri, Redlands, California) under low/no traffic conditions to simulate ambulance transport] are combined to predict the probability of good outcome (disability free at 90-days post stroke) if drip and ship or mothership transport is used at the population level. These are then compared to determine which transport option will predict best outcomes at the population level.

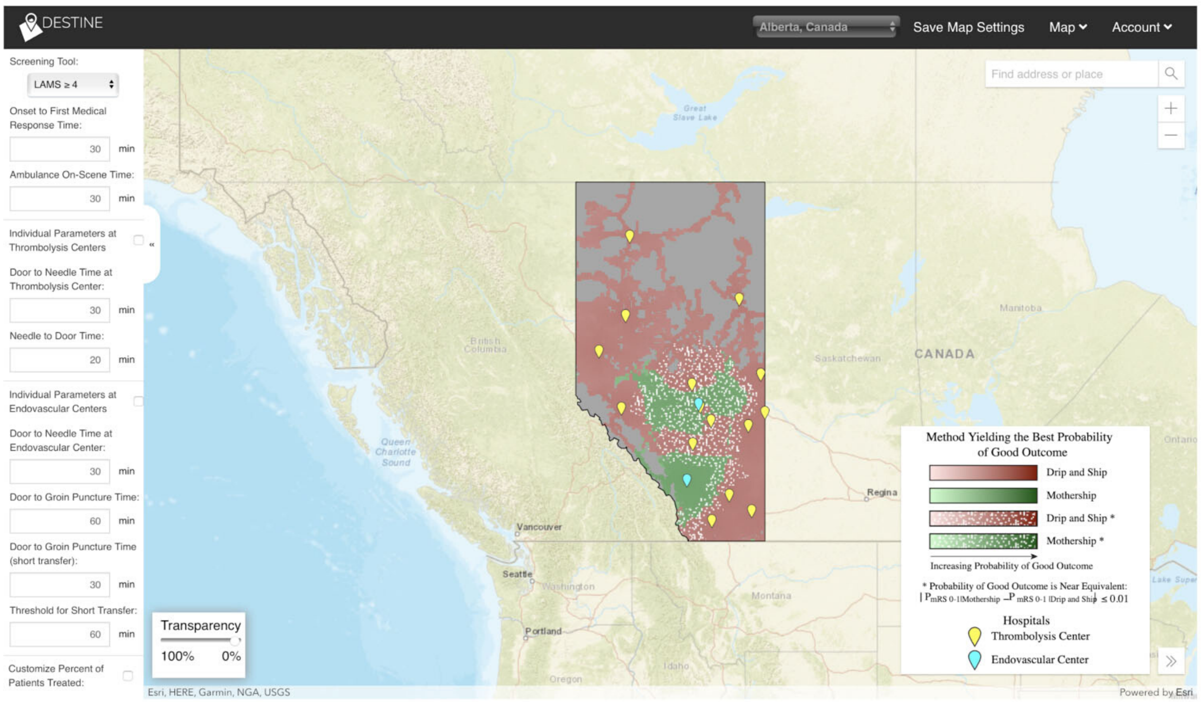

Figure 5. Transport map generated by DESTINE software for Alberta, Canada. In the map, areas in red indicate that drip and ship predicts best outcomes for patients at the population level. Green areas indicate that mothership predicts best outcomes for patients at the population level. Areas with white stippling over either colour indicate that the difference in predicted outcomes between drip and ship and mothership in this area is less than 0.01 (or 1%).

The user can fully explore their system with this interactive map, having the ability to zoom in to view road infrastructure, view the predicted probability of good outcome for a specific area, and compare different maps side by side. This allows the user to understand what transport decisions are best in their specific geography under current conditions. In addition, they can look at how transport protocols would change if system efficiency were to change.

Other Use Cases

The software does more than just compare drip and ship with mothership, it considers several different thrombolysis and EVT centre combinations for each piece of geography so not only will the user know if drip and ship or mothership is best for patients but drip and ship or mothership to which specific hospitals.

This allows the software to compare population level outcomes under several different system level paradigms. For example, in cities close to a state (or even international) border, could transport to a closer centre which is across the border be better for patients? If so, how much better? DESTINE's software can answer questions like this. Curious about the impact of adding or removing a stroke centre in your health system? The software can demonstrate the impact on the population level outcomes and also on the changes needed in your stroke transport strategy to reflect this.

Finally, other transportation scenarios, such as drip and drive transport (where the interventionalist leaves the EVT centre in order to meet the patient and perform the EVT procedure at the thrombolysis centre) or use of a mobile stroke unit can also be added to the software to quantify the benefit of implementing these methods.

Impact

DESTINE's software has been successfully piloted in four countries across the globe: the United States, Northern Ireland (UK), Sweden, and Japan. The software is currently deployed in Northwest Germany. These clients have used DESTINE's software to analyze their stroke systems, determine the most optimal transport strategy for stroke patients in their region, and identify inefficiencies in their stroke system that may be adversely affecting patient outcomes. Some jurisdictions have gone on to successfully lobby for change in stroke transport protocol at the government level. Others have used the software output in public consultation on the reorganization of stroke systems.

"These maps allowed SNIS greater certainty in putting forth legislation on the best transportation method for stroke patients. Additionally, these maps also provided impetus for designated stroke hospitals to improve their efficiency of treatments, and which hospitals are best to focus on based on geography."

– Marie Williams, CAE (Society of NeuroInterventional Surgery, Executive Director)

On a more clinical level, we have clientele using the software to evaluate the effect of adopting a new patient screening tool. Another group is using the software to model the impact of adding a completely new transport strategy (drip and drive) to their existing stroke system. They have used DESTINE's software to show that this new transport strategy will result in superior patient outcomes in many areas of their health region.

About DESTINE Health Inc.

DESTINE Health Inc. was co-founded by Drs. Noreen Kamal and Jessalyn Holodinsky in 2018 following 3 years of research on the pre-hospital triage and transport of stroke patients within the Departments of Clinical Neuroscience, Community Health Sciences, and the Calgary Stroke Program (University of Calgary). Noreen and Jessalyn knew that the results of their research program could help stroke systems improve their transport protocols and patient outcomes worldwide and created the DESTINE Health software to make the results of their research accessible to health systems across the globe. DESTINE Health is led by CEO Jennifer van Zelm, an engineer and business consultant that wanted to work on something impactful. DESTINE is dedicated to incorporating the latest scientific research into our decision support tool, as such, we receive advice and mentorship from an independent scientific advisory committee of stroke experts from across the globe.

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