Geographic Information Software Programs' Accuracy for Interfacility Air Transport Distances and Time

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Abstract

Introduction: This study aimed to evaluate consistency/predictability of interfacility flight times (IFFTs) and accuracy of geographical information system (GIS) software packages for estimating IFFT.

Methods: This retrospective study conducted by a program using a Bell 206 assessed the first 1000 IF transports occurring on 137 "runs" (ie, referring-receiving hospital pairings) made at least twice. GIS IFFT estimates using Google Earth™ (GE) and ArcGIS™ (AG) were compared against actual IFFT using linear regression; univariate analysis included assessment of medians with 95% binomial exact confidence intervals (CIs). Interrater agreement for GIS was assessed with κ.

Results: GE and AG estimates fell, respectively, within 1 mile of actual in 136/137 runs (99%, 95% CI 96%-100%) and 130/137 runs (95%, 95% CI 90%-98%). GE- and AG-predicted IFFT strongly ($P < .001$) correlated with, underestimating by about 2 minutes, actual IFFT (GE: r2 0.93, coefficient 0.98, 95% CI .97-1.00; AG: r2 0.93; coefficient 0.98, 95% CI .96-1.0). GE and AG had statistically equivalent (κ > .8), "almost-perfect," interrater agreement.

Conclusion: IFFTs for same-run helicopter EMS transports in our rural state setting are characterized by little variability. GIS is highly accurate in predicting IF logistics, with public-domain GE performing as well as more expensive AG.

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Introduction

Growth in the emphasis on transport for time-windowed medical interventions (eg, cardiac catheterization and stroke care)[1-4] is increasing the importance of characterizing potential time advantages of helicopter emergency medical services (HEMS). An increasing number of clinicians, policy makers, and systems researchers are using estimated ground and/or air mileage (and transport times) to assess the appropriateness of HEMS versus ground emergency medical services (GEMS) use for a given transport. Much of the literature uses 2 geographic information software (GIS) programs: Google Earth (GE; Google Inc., Mountain View, CA) or ArcGIS (AG; Esri, Redlands, CA).

Despite the long-standing emphasis on time savings as a possible mechanism for HEMS benefits, there are relatively few data evaluating the precise nature of time saved by air medical transport. Some studies have calculated time savings associated with air transport compared with ground transport, but they have largely used actual HEMS versus estimated GEMS times.[2,5] Moreover, few have examined the accuracy (ie, closeness to "truth") of GIS-generated estimates for HEMS transport, and there are essentially no data addressing the question of differential reliability of different GIS systems.

This study's aims were to use actual interfacility air transport distances obtained from flight records to address the following 3 questions:

1. What is the spread? In other words, what are the consistency and predictability of actual air transport times for repetitions of the same interfacility run? This question's importance lies in the fact that if the spread of actual transport times is substantial, then it would be impossible to try and assess whether GIS software could consistently predict those transport times.
2. What is the accuracy (eg, closeness to "truth") of flight logistics calculations as executed by GIS software?
3. What is the interrater variability of different rater estimations of air transport distances using GIS software?

Because few data address the range of flight times encountered for "same-run" interfacility transports between a given referring and receiving hospital pairing, improved understanding of the breadth of range of such flight times would benefit clinical decision making surrounding potential time savings of air versus ground transport. The demonstration of a narrow "spread" of expected flight times for a given transport run would be beneficial in removing (to some degree) 1 source of variation in estimating air transport logistics.

Additionally, in answering questions 2 and 3 provided earlier, there is the additional following "endpoint": Is public domain GIS software sufficiently accurate for executing air transport logistics estimates? The demonstration that public domain software is sufficiently reliable for transport logistics calculations would render those calculations more accessible (in terms of both cost and ease of use) to clinicians and prehospital systems planners.

Methods

Study Setting

The study was conducted in a large rural state in the Southwestern United States. The study center's institutional review board approved the investigation. No patient information or related "protected" data were accessed as part of this study. All transports included in the study set originated and ended within the study state. All referring and receiving hospitals had on-site (ad hoc or permanent) helipads.

Study HEMS Program

The study HEMS program is a multistate service that operates approximately 150 aircraft in 15 states. During the time study flights were accrued, the service operated 9 bases in the study state; these 9 bases accounted for 96% of the study flights. The overall mission profile of the study HEMS service's bases is characterized by approximately 2,400 flights annually, of which 75% are interfacility transports.

The study database incorporated an additional 50 in-state flights (4% of the study group) executed by the study HEMS program's neighboring-state aircraft. The study program operates Bell 206 LongRanger aircraft almost exclusively. The cruise speed of the aircraft was established before the study, for purposes of study calculations, to be 120 statute mph. A small number (n = 13) of flights by the study service were excluded because they occurred in a different aircraft (the Bell 407, which is faster than the LongRanger).

Constitution of Study Database

The study's initial eligibility criteria were first defined including interfacility transport, the referring and receiving hospital within the study state, and executed by study HEMS using a Bell 206 LongRanger. Next, the study defined a "run" as a transport between a specific referring and receiving hospital pairing.

Flights were eligible for inclusion in the study if they executed a run that occurred at least twice. Flights were not eligible if there were unexpected deviations from the planned flight plan because of aviation/weather issues (n = 1) or if there was intratransport rerouting (n = 1).

Therefore, the study database was constituted by the first 1,000 transports of 2013 that met the preceding criteria. This translated into a study period of January-October 2013 that included the n of 1,000 transports. The 1,000 study flights occurring between referring-receiving hospital pairings with at least 2 transports were drawn from the 1,206 in-state interfacility transports during the study period. These 1,000 study flights were conducted for 137 discrete runs (ie, referring-receiving hospital pairings).

Definition of Gold Standard Logistics and a Priori Cutoffs for Accuracy and Agreement

The accuracy of software-calculated times and distances was judged against the gold standard of electronic medical record (EMR)-logged actual air transport mileage and times. The study service's "EMR" includes dispatch- and pilot-entered logistics data that are entered in real-time when a transport is executed; these data (Garmin GPSMAP 496 version 4.70; Garmin International, Inc., Olathe, KS) constituted the gold standard used in the study.

The following a priori cutoffs for the accuracy and agreement were defined: 1) flight mileage as determined by different methods was defined as being "the same" if the rounded-to-nearest-mile results were within 1 mile of each other and 2) flight times as predicted by GIS were defined as being "reasonably accurate" if within ±10 minutes of actual flight time and "very accurate" if within ±5 minutes of actual flight time.

For the interpretation of kappa (κ) interrater agreement results, the statistical software used (STATA 13MP; Stata Corp, College Station, TX) uses the following cutoffs: 1) 0.00-0.20: slight, 2) 0.21-0.40: fair, 3) 0.41-0.60: moderate, 4) 0.61-.80: substantial, and 5) .81-1.0: almost perfect. These cutoffs and exact wordings were used in this study.

Calculation of Logistics Using GIS

Two GIS programs were used: GE and AG. For the 137 runs, GE and AG were used to generate estimates of 1) straight-line distances between hospitals' helipads and 2) flight time, which was obtained by applying a 120-mph aircraft cruising speed to the GIS-calculated flight distance.

Within each GIS program, the flight (straight-line) distance between hospitals was calculated using the referring hospital helipad and receiving hospital helipad as starting and ending points. All referring and receiving hospitals had on-site helipads and in no case was there more than a 0.1-mile separation between a hospital's main entrance and its helipad.

Assessment of Accuracy: Agreement Between GIS-calculated and Gold Standard Logistics

Using a priori plan, the accuracy of GIS-calculated logistics data was assessed by 2 main methods. The methods were applied to flight distances and flight times.

The first calculation determined the proportion of GIS-calculated data that fell within 1 mile (for distance) or 1 minute (for time) of EMR data. These proportions were calculated with binomial exact 95% confidence intervals (CIs).