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Automated Identification of Hospital-Acquired Venous Thromboembolism

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Introduction

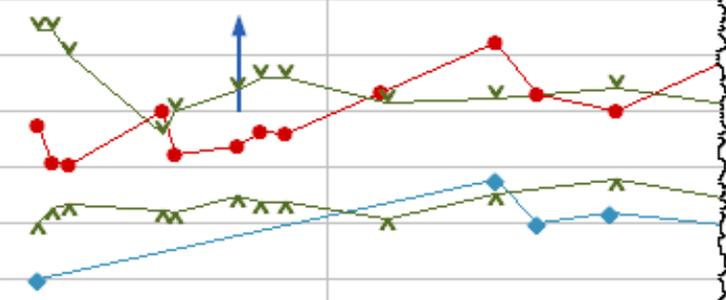
- Venous thromboembolism (VTE)
- Present on admission
- Hospital-acquired ← potentially preventable complication
- Decrease of hospital-acquired VTE indicates success of efforts to prevent inpatient VTE

Cave **Probleme/Diag.** **Information** **Austrittsmanagement** **Verlaufsber.** REA: **Ja** IPS: **Ja** BG:

Neu ▼ Mi 19.02.2014 ▼ bis Sa 22.02.2014 ▼ Zeige Alles ▼ + gelöschte - pausierte kompakt sep. Zeilen Exp

| Name | Inhalt | Mi 19.02.14 | Do 20.02.14 |
|-----------------------------|--|---|----------------|
| Spitaltag | SPT | SPT 1 | 2 |
| Warnungen / Hinweise | !Warnung zur Prävention der venösen Throm... | | |
| Mitteilungen | | | PFLEGE |
| REA | REA: Ja / IPS: Ja / Intubation: Ja, Notfall-Nr. 1... | REA: Ja / IPS: Ja / Intubation: Ja, Notfall-Nr. 144 / | |

| BD | Puls | Temp |
|-----|------|------|
| 200 | 140 | 41 |
| 170 | 120 | 40 |
| 140 | 100 | 39 |
| 110 | 80 | 38 |
| 80 | 60 | 37 |
| 50 | 40 | 36 |



| Vitalparameter | | | | | |
|-----------------------|---------------|--|--|--------|--------|
| ! Blutdruck | | | | 170/90 | 145/83 |
| ! Puls | | | | 81 | 107 |
| Temperatur | X - 0 - 0 - 0 | | | 36 | 37.2 |

| Verlaufsparameter | | | |
|--------------------------|-----------------------|----|---|
| Gewicht | (Mo, Mi, Fr um 08:00) | X | |
| Grösse | einmalig | | X |
| O2-Sättigung | | 95 | |
| Überwachung Stuhlgang | | | Ø |

| Laborparameter | | | |
|-------------------------------------|---|------|------|
| Bilanzierung | | | |
| Scores | | | |
| Medikamente enteral | | | |
| Medikamente syst. parenteral | | | |
| Infusionen | | | |
| NaCl 0.9% | Alle 24 Std. 1000 ml über 24 h (14:00) als Inf... | 1000 | 1000 |



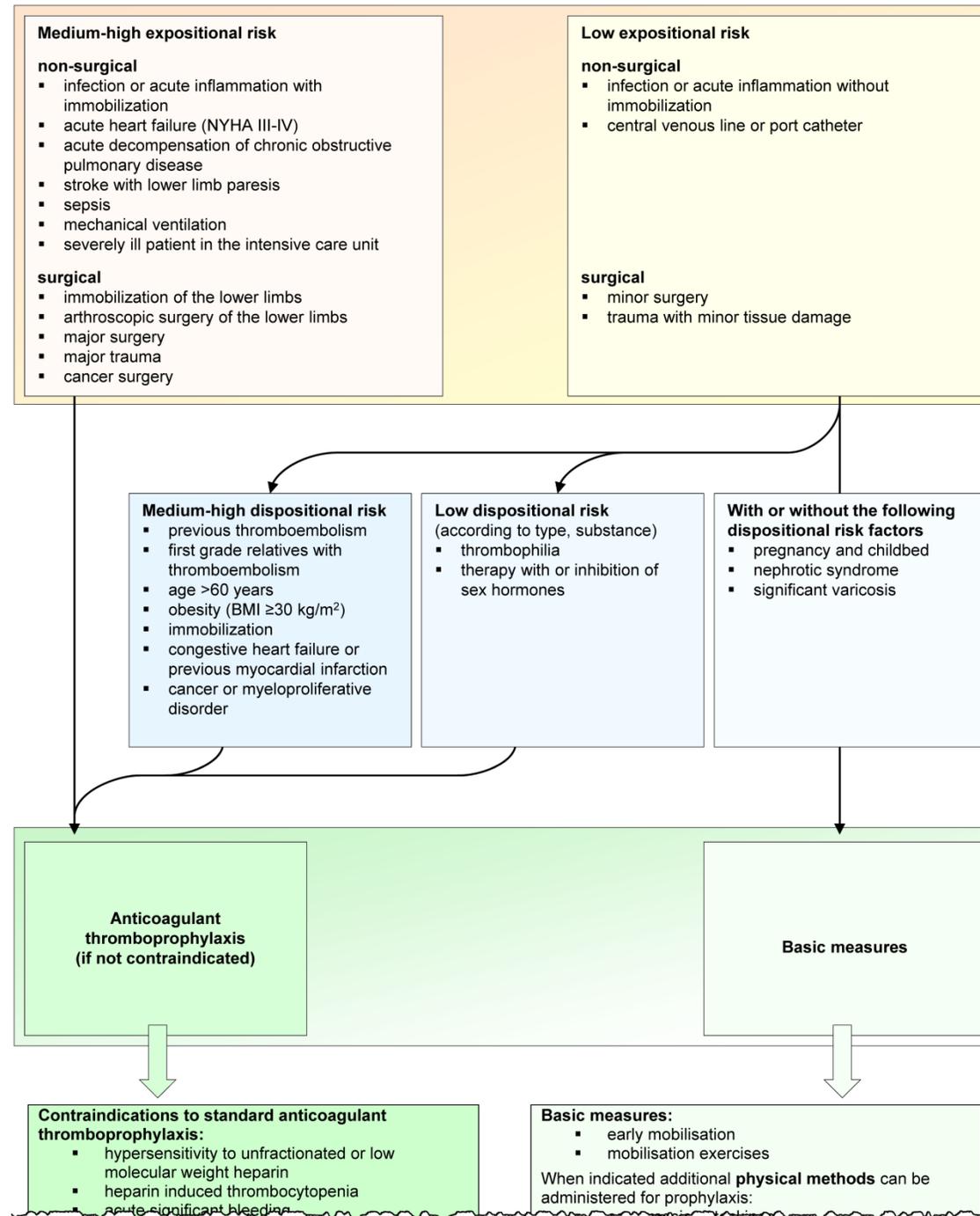


Table 1 ICD-10 diagnosis codes used to determine differences in the frequencies of bleeding due to anticoagulants, other bleeding events, heparin-induced thrombocytopenia and VTE events (adapted from Huo *et al*²⁸ and Casez *et al*²⁹ and updated)

| Event | ICD-10 diagnosis codes |
|----------------------------------|--|
| Bleeding due to anticoagulants | D68.3* |
| Other bleeding events | D69.9*, H11.3*, H31.3*, H35.6*, H43.1*, H45.0*, I60.*, I61.*, I62.*, K22.8*, K62.5*, K66.1*, K92.0*, K92.1*, K92.2*, M25.0*, R04.*, R23.3*, R31, R58 |
| Heparin-induced thrombocytopenia | D69.53 |
| VTE | I26.*, I80.1*, I80.2*, I80.3*, I80.8*, I80.9*, I82.1*, I82.2*, I82.3*, I82.8*, I82.9*, O22.3*, O87.1*, O88.2* |

The * character is used as a wildcard that matches zero or more numeric digits. ICD, International Classification of Diseases; VTE, venous thromboembolism.

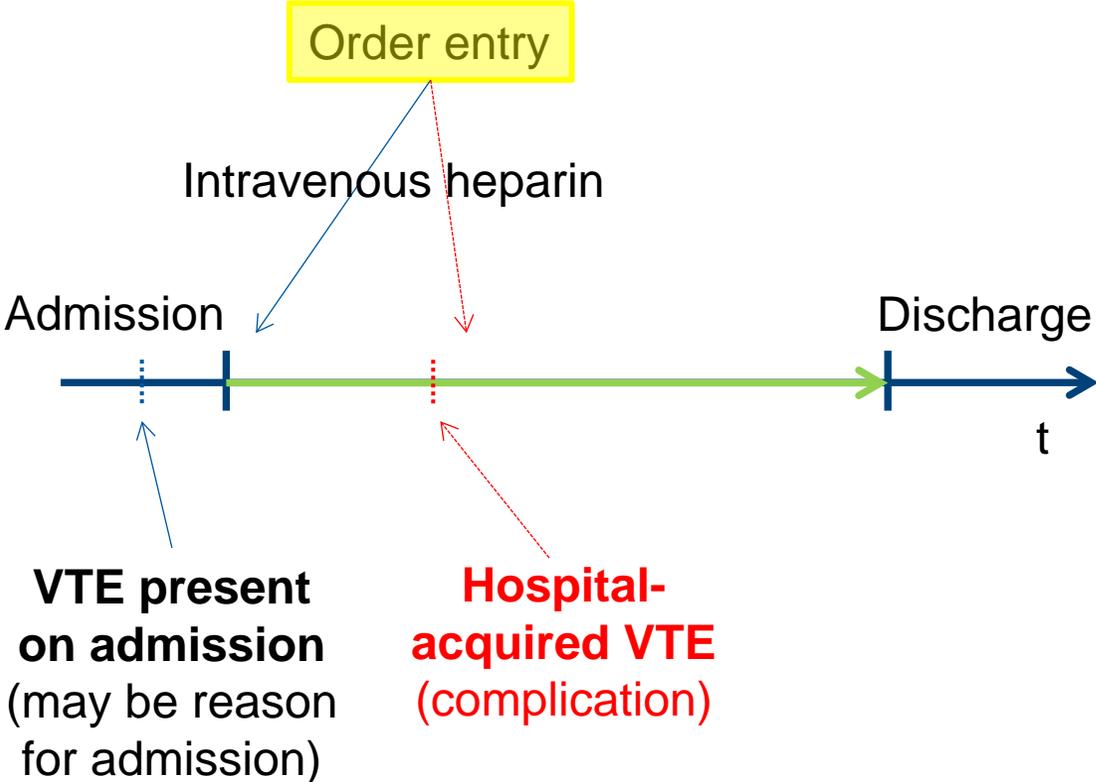
J Am Med Inform Assoc. 2014 Oct;21(e2):e297-303.

Clinical outcome assessment

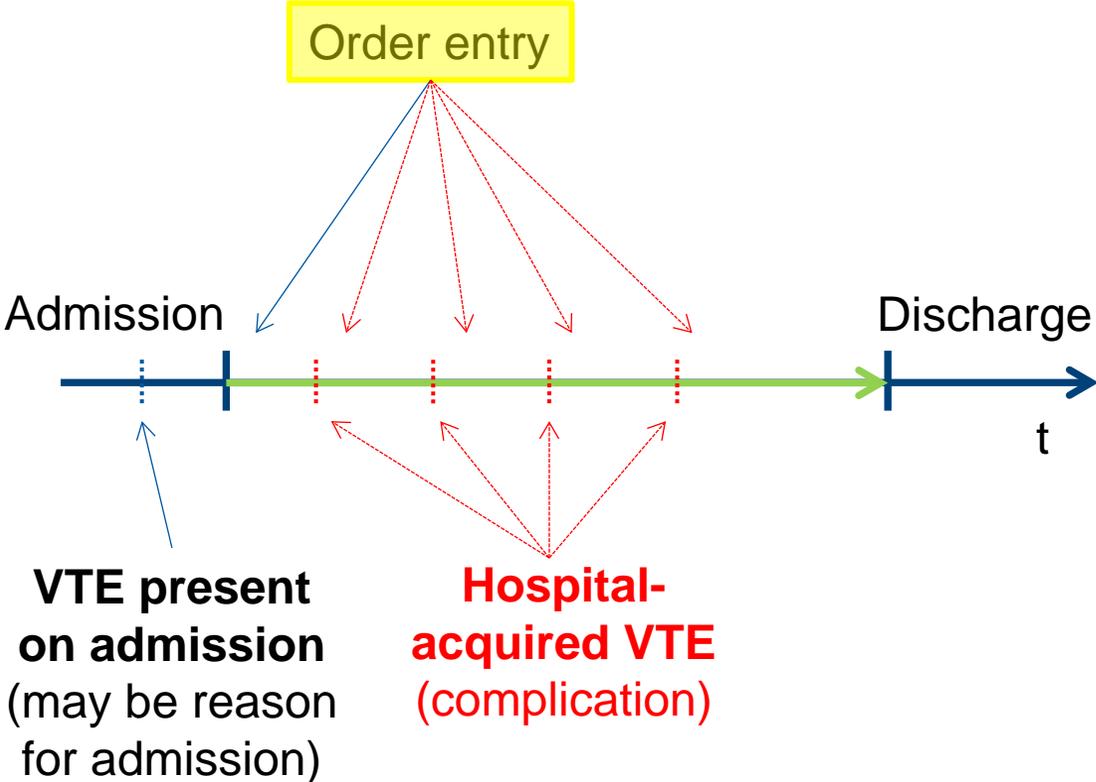
| | Intervention group | | | | Control group | | | |
|----------------------------------|--------------------|------|-----------------|------|-----------------|------|-----------------|------|
| | Baseline period | | Reminder period | | Baseline period | | Reminder period | |
| | # of patients | % | # of patients | % | # of patients | % | # of patients | % |
| Bleeding due to anticoagulants | 6 | 0.18 | 4 | 0.12 | 1 | 0.02 | 1 | 0.02 |
| Other bleeding event | 29 | 0.87 | 31 | 0.93 | 11 | 0.26 | 14 | 0.3 |
| Heparin-induced thrombocytopenia | 1 | 0.03 | 3 | 0.09 | 0 | 0 | 0 | 0 |
| VTE event | 19 | 0.57 | 13 | 0.39 | 12 | 0.28 | 10 | 0.21 |
| Total number of patients | 3321 | 100 | 3332 | 100 | 4256 | 100 | 4669 | 100 |

J Am Med Inform Assoc. 2014 Oct;21(e2):e297-303.

Hospitalized patients



Hospitalized patients



Inclusion criteria

- Inpatients
- Discharged from Brigham and Women's Hospital between January 2009 and April 2014
- Length of stay ≥ 24 hours
- With acute venous thrombosis or pulmonary embolism (ICD-9 codes)
- In “admitting diagnosis field” (i.e. “present on admission”), or in one of up to 50 discharge diagnoses
- Patients received either heparin, dalteparin, enoxaparin, alteplase, rivaroxaban or fondaparinux

Structured predictors

- Drug orders (heparin, dalteparin, enoxaparin, alteplase, rivaroxaban, fondaparinux)
- Route of administration
- Dose information (high vs. low vs. “on median”)
- Time from admission to order entry for each considered drug therapy
- Demographics (age, gender, race, language)
- Length of stay
- Admission service
- Discharge service
- Transfer destination of the patient after discharge
- Patient is alive or died during hospitalization or within 30 days after discharge

Modeling

- Single decision tree using all available predictors
- First random forest (5000 trees) using prospective predictors only (demographics, admission service, time to order a drug, route and dose information for each drug)
- Second random forest (5000 trees) using all available predictors

- Half of the data served as calibration set, half as validation set
- R version 3.1.0 (R Foundation for Statistical Computing, Vienna, Austria)
- Presentation of accuracy and positive predictive value (PPV)



Results

- A total of 5374 patients were included

VTE present on admission:

- 1262 patients (23.5%)
- Median time to order drug therapy was 2.5h (IQR 1.3-5.0)

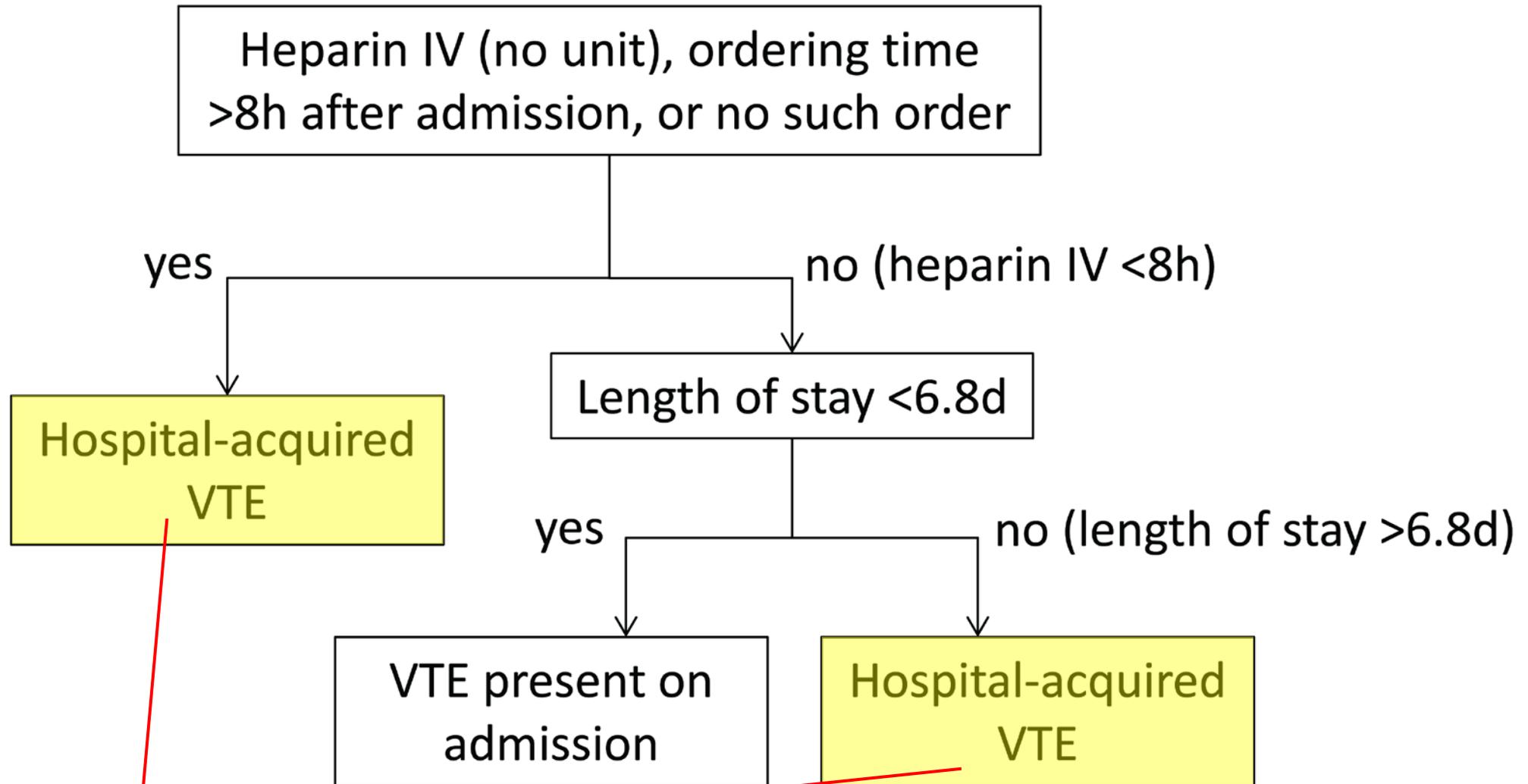
Hospital-acquired VTE:

- 4112 patients (76.5%)
- Median time to order drug therapy was 4.2h (IQR 1.7-18.2)

Decision tree

- Using all available predictors
- Accuracy of 78.8%
- PPV of 83.3% for the classification of hospital-acquired VTE





PPV of 83.3%

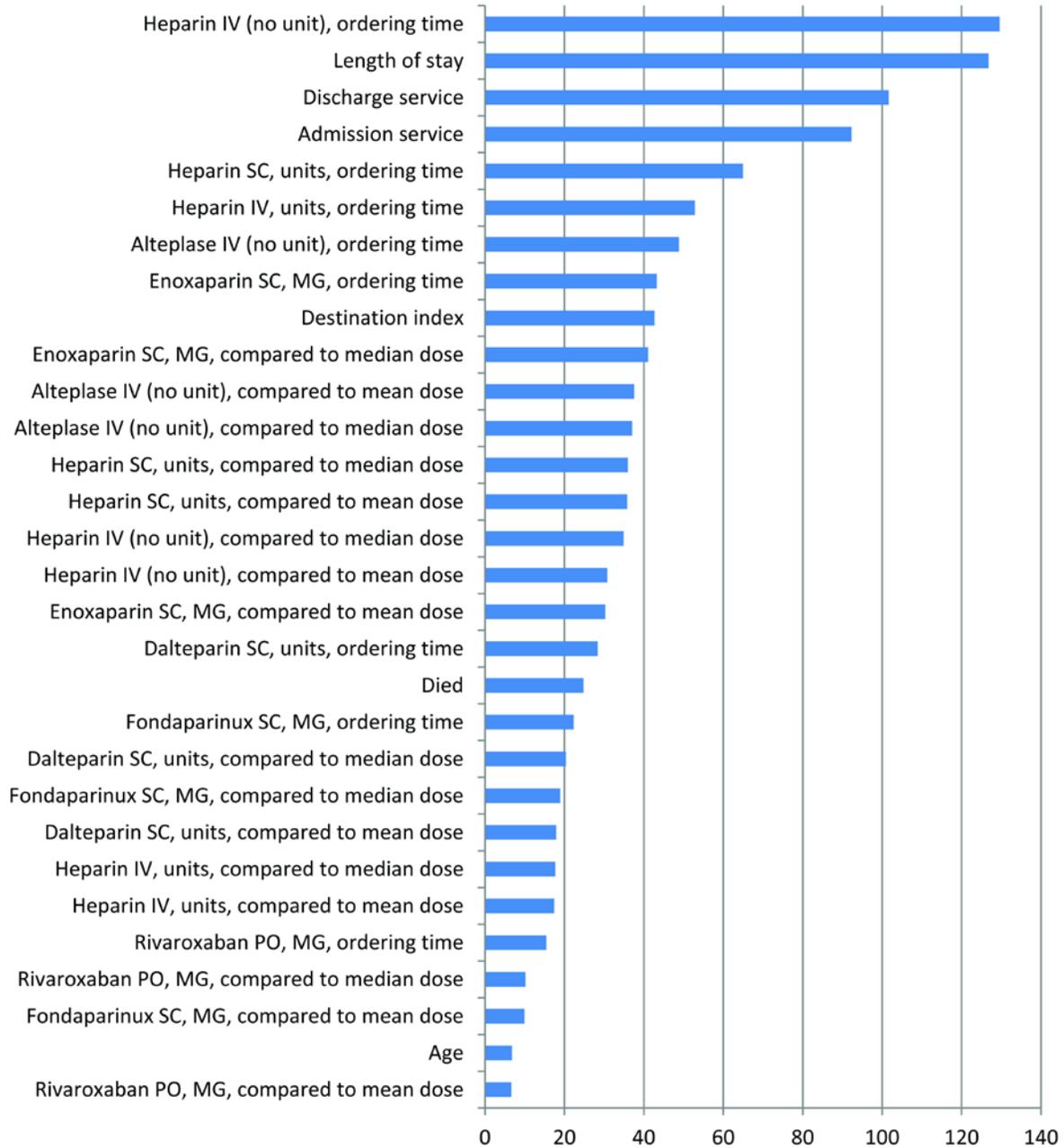
First random forest

- Only prospective predictors, available in real time (i.e. demographics, admission service, time to order a drug, route and dose information for each drug)
- Accuracy of 79.7%
- PPV of 85.3% for the classification of hospital-acquired VTE

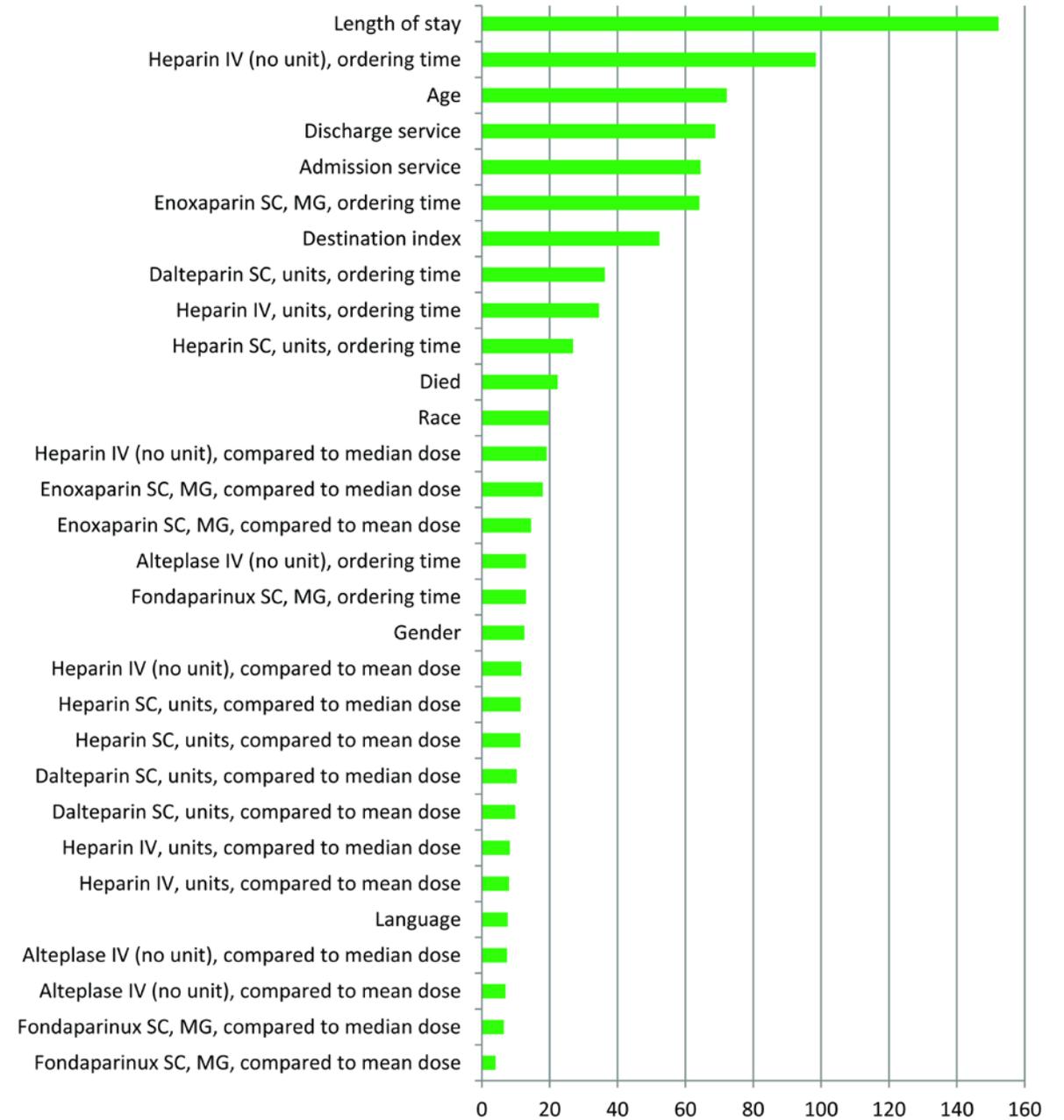
Second random forest

- Using all available predictors
- Accuracy of 81.7%
- PPV of 87.8% for the classification of hospital-acquired VTE

Mean Decrease Accuracy



Mean Decrease Gini



Conclusions

- The presented decision tree, considering the first order for intravenous heparin and the length of stay, could immediately be implemented as a first step to identifying patients with hospital-acquired VTE.
- Random forests could help to evaluate interventions to improve VTE prophylaxis regimens for inpatients, where costly chart reviews are needed to differentiate between VTE present on admission and potentially preventable complications.

