

Eyal Zimlichman^{1,2}, Dalia Argaman³, Shiraz Levkovich³, Rina Weizman³, Zvika Shinar³¹The Center for Patient Safety Research and Practice, Division of General Medicine, Brigham & Women's Hospital and Harvard Medical School, Boston, MA, ²Quality Management, Sheba Medical Center, Tel Hashomer, Israel, ³EarlySense Ltd., Ramat-Gan, Israel

Introduction

Use of technology to alert and prevent patients fall has a limited success. This is partially because only half of the falls are related to bed-exit, but it is also related to the caregiver's response time, i.e. the time between the alert and the caregiver actually arriving at the bed-side and aiding the patient (Figure 1).

This study quantified the problem by **measuring response time** in a multi-center implementation of a system (EarlySense ltd.) that measured caregivers' response time. In addition, this study examined the performance of a novel implementation of a **predictive algorithm** that foresaw bed-exits during the night, to allow a bridge over this inevitable response time.

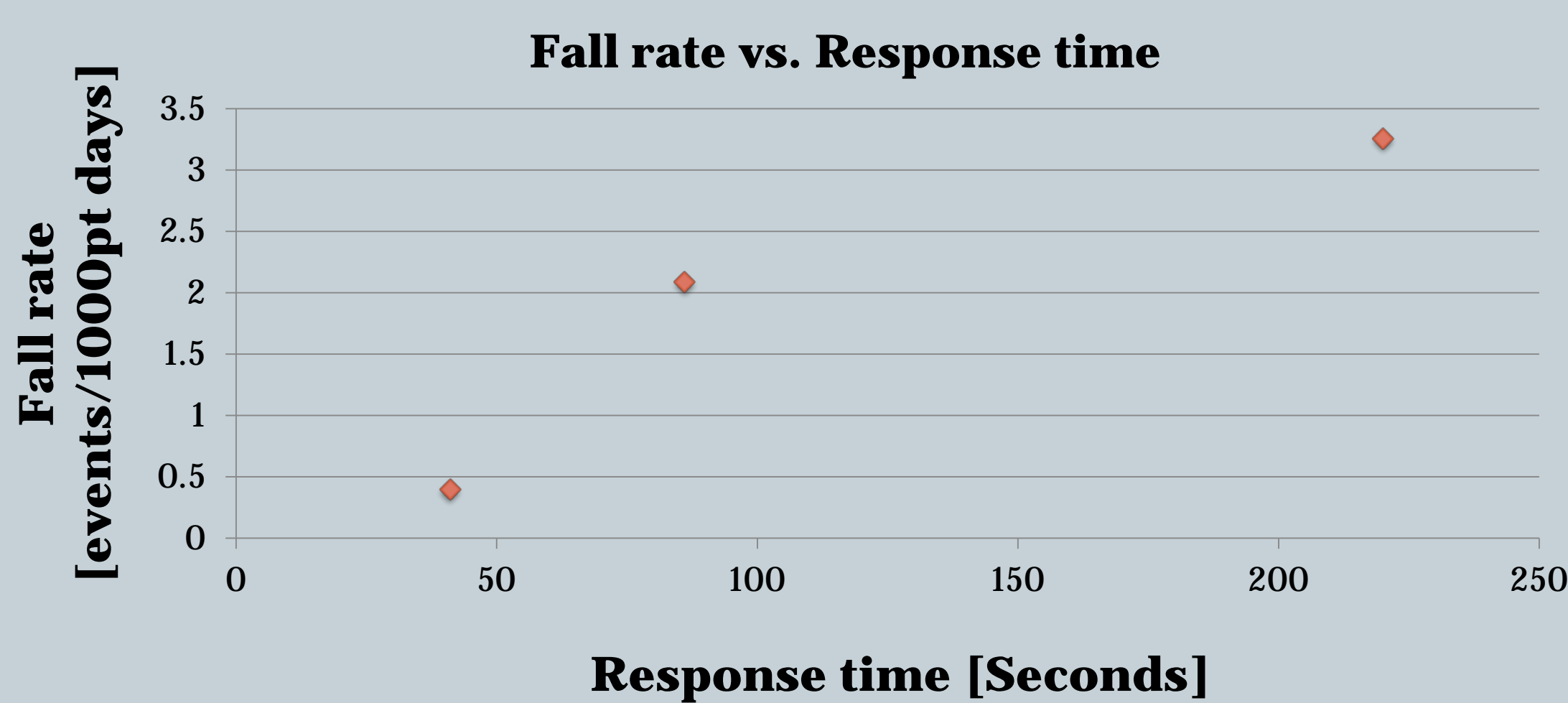


Figure 1: number of falls per 1000 patient days vs. response time, in 3 different sites over a period of 6 months.

Methods

The system used in this study is composed of a piezo-electric sensor and a processing unit. The sensor was placed under-the-mattress and measured bed-occupancy as well as motion, heart rate, and respiration¹.

Measuring response time

We summarized the response time of over 1 million monitoring hours in 3 different sites over a period of 5 years. Sites 1 & 2 are general medical surgical units, in 2 different hospitals. Site 3 is a long term care facility.

Validating a novel bed-exit prediction algorithm

A 3-level predictor was defined and implemented using patterns that the system has learned to be predictive of bed exit.

Retrospective analysis of data recorded in two clinical sites (Sites 1 & 3), together with retrospectively calculated bed exit detection were used to evaluate the performance of the predictive algorithm.

Prospective analysis included real-time testing of the proposed algorithm, in the hospital. This was done only during nighttime between 23:00 and 06:00 the next morning. An observer responded to every prediction alert and documented whether it led to an actual bed exit

Results

Median **Response time** for bed exit alert varied from 49-91 seconds (see table 1), with Site 1 representing a unit with a very strict fall-prevention program.

Retrospective analysis results for bed exit prediction indicator of sites 1 & 3 are presented in Table 2. Positive predictive values (PPV) of 37% & 39% with sensitivities of 53% & 64% and average time of 72 & 57 seconds before actual bed exit was found. Higher PPV could be expected if sitting was used as success criteria instead of actual bed-exit.

Results – cont.

For the **prospective** evaluation of the predictor, successful prediction was counted, for levels 1 or 2, if the observer found the patient to be awake; and for level 3, if the patient was found sitting in bed (at night time). Results (Table 3) showed PPV of 38%, 56% and 67% for predictor levels 1, 2, and 3 respectively.

Table 1

Site #	Rec. time [hours]	# recorded bed-exits	Response time [sec]	
			Median	25 th - 75 th
1	430,420	10,922	49	41 - 69
2	555,514	25,614	91	79 - 113
3	394,946	6,691	77	57 - 93

Response time statistics in 3 different sites (3 different hospitals) over accumulative period of 5 years.

Table 2

Site #	Number of nights	PPV (%)	Sensitivity 0:300 [sec]	Time before BEX [sec]
1	667	37	53	72
3	543	39	64	57

Retrospective results of predictor level 3. Success criteria for the predictor was if the patient actually left the bed. Positive Predictive Value was 37-39% (i.e. ~4/10 of predictor events were followed by bed-exit). Median time before bed-exit was 72 & 57 seconds. As this is a retrospective analysis – predictor indications when subject was sitting in bed could not be counted as successful.

Table 3

Predictor level	Total events	Success	Fail	Unknown	PPV
1	196	75	67	54	38%
2	260	146	38	76	56%
3	37	25	0	12	67%

Prospective results for the different predictor levels. In 2 out of 3 indications of predictor level 3 – patient was found already sitting in bed, instead of lying down!

Conclusion

We have found a lag of approximately 50-90 seconds between the bed exit alarm and caregiver's response. An algorithm developed to predict fall/bed exit was found to precede the event by 57-72 seconds with a positive predictive value of up to 67%. Being able to predict ahead of time patient falls or bed exit will allow timely assistance at the bed side and potentially prevent falls. Further research is required to examine this possibility in an interventional controlled clinical trial.