Empirical Study of Medical IoT for Patients with Intractable Disease at Home

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- Objectives
 - Promote safety of patients attached highly-controlled medical devices, such as an artificial ventilator, for home use
 - Define consistent alarm functions of highly-controlled medical devices in home
- Background
 - Patients with intractable diseases are returning to home
 - Each ventilator has its own interface/meanings in alarming
 - Missing alarms happen so often
 - False-alarms are raised so often (Crying Wolf)
- In this paper as the first step
 - Need to know what kind of alarms are raised in real use environment and how often
 - Investigate alarms for treatments
 - One solution is to have a decision tree of alarm-raise based on each alarm-time duration



The number of patients taking home mechanical ventilation in Japan is increasing.



NIPPV : Non invasive Positve Pressure Ventilation, TPPV : Tracheotomy Positive Pressure Ventilation



Many ventilators are designed for hospital use, but have been brought to home.











Missing Alarm









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Crying Wolf

One research demonstrated that **72%** to **99%** of clinical alarms are false.

The high number of false alarms lead to desensitization to alarms and missing alarms.



Patient deaths





The alarm delivery system for patients with intractable diseases at home





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Research of Alarms of Home Medical Equipment

Patient: a pediatric patient with intractable disease who had received a tracheostomy and attached to an artificial ventilator and pulse oximeter at night.

Data collection period: one year from June 1st 2018 to May 31st 2019

The total number of measured days : 327 days (artificial ventilator) 269 days (pulse oximeter)

Pulse oximeter





Frequency and duration of alarms

	Count 0/		Frequency		D	uration		Elapsed	
Alarm Code	Count	%	[/day]	Min	25%	Median	75%	Max	time
Pulse Oximeter			_						
motion	139811	90	1260	2	2	2	4	114	
pulse_search	5259	3.4	47.41	2	2	2	6	94	
sensor_off	3662	2.4	33.01	2	2	4	6	148	
loss_of_pulse	3603	2.3	32.48	2	2	2	4	66	
loss_of_pulse_with_motion	2071	1.3	18.67	2	2	4	6	98	110 days
spo2_lo	662	0.43	5.968	2	2	6	8	70	22:10:45
pulse_rate_lo	246	0.16	0.6 2.218	2	2	4	8	94	
pulse_rate_hi	4	0.026	0.03606	4	6	8	31	92	
no_sensor	1	0.00064	0.009015	8	8	8	8	8	
Subtotal	155319	100	1400	2	2	2	4	148	
Artificial Ventilator									
peak_press_insp_lo	13304	89	94.26	1	3	4	6	214	
peak_press_hi	1075	7.2	7.616	1	2	3	4	11	111 dava
insp_time_over_2	361	2.4	2.577	1	2	2	3	4	2.21.20
others	173	1.2	1.226	1	1	1	1	2	3.21.20
Subtotal	14913	100	105.7	1	3	4	5	214	
Total	170232		1506	1	2	2	5	214	



Decision of alarm priority and medical treatment assuming alarm-priority "Middle"





Alarm priority and time duration for notification

Alarm Code		Initial Alarm				Es			
		Priority	Duration [sec]		c]	Priority I		uration [see	2]
Pulse Oximeter		> 75th percentile			tile	ile > 75th percenti			
	motion	-		_					
	pulse_search	L		> 6		M		> 12	
	sensor_off	L		> 6		M		> 12	
	loss_of_pulse	L		> 4		M		> 8	
	loss_of_pulse_with_motion	L		> 6		M		> 12	
	spo2_lo	М		> 8		Н		> 16	
	pulse_rate_lo	М		> 8		Н		> 16	
	pulse_rate_hi	Μ		> 31		Н		> 62	
	no_sensor	L		> 8		M		> 16	
Artificial Ventilator									
	peak_press_insp_lo	М		> 6		Н		> 12	
	peak_press_hi	М		> 4		Н		> 8	
	insp_time_over_2	М		> 3		Н		> 6	



Expected alarm reduction effect

Alorm Codo	Count	Deduction		Expected Alar	Expected Alarm Reduction			
Alarm Code	Count	Reduction	Rate [%	Count	Rate [%]			
Pulse Oximeter								
motion	139811		100	139811				
pulse_search	5259		75	3944				
sensor_off	3662		75	2747				
loss_of_pulse	3603		75	2702				
loss_of_pulse_with_motion	2071		75	1553				
spo2_lo	662		75	498				
pulse_rate_lo	246		75	185				
pulse_rate_hi	4		75	3.0				
no_sensor	1		75	0.75				
Subtotal	155319			151442	97.5			
Artificial Ventilator								
peak_press_insp_lo	13304		75	9978				
peak_press_hi	1075		75	806				
insp_time_over_2	361		75	271				
Subtotal	14913			11055	74.1			
Total	170232			162497	95.5			



Conclusion of this presentation and future works

- Implemented an alarm-delivery system for a pediatric patient with intractable disease with cooperation of the family of the patient under the study approval
- Proposed a prototype false-alarm reduction mechanism in the system and investigated alarms for one year
- Focused on alarm duration of alarm codes and their triggering mechanism
- Currently working on alarm optimization and designing an alarm delivery taking advantage of home IoT network
- In future, expect consistent alarm meanings of medical devices at home and also the hardware interfaces



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Thank you