Evaluation Of Use Of Wearable Sensor Garment In Home Screening For Sleep Apnea Events

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Plan of presentation

- **Introduction and problematic**
- **Proposed solution**
- **Setup and Clinical trials**
- **Results**
  - Position detection
  - Sleep apnea event detection
- **Conclusion**

Introduction

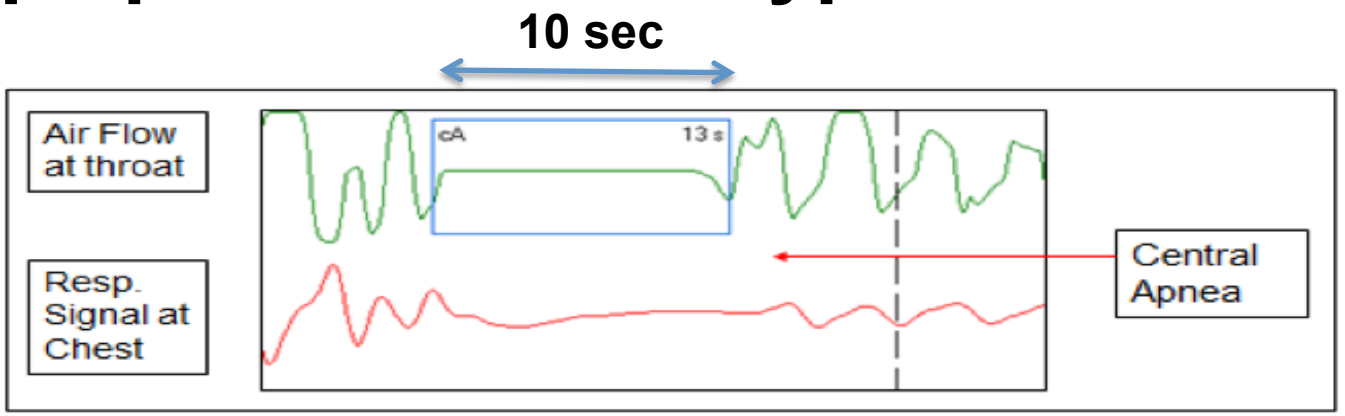
A sleep apnea is characterized by periods where breathing stops entirely or significantly reduced during sleep for 10sec or more.

- Sleep apnea degrades sleep quality
- Daytime somnolence
- Morning headache
- Increasing risk of cardiovascular related death

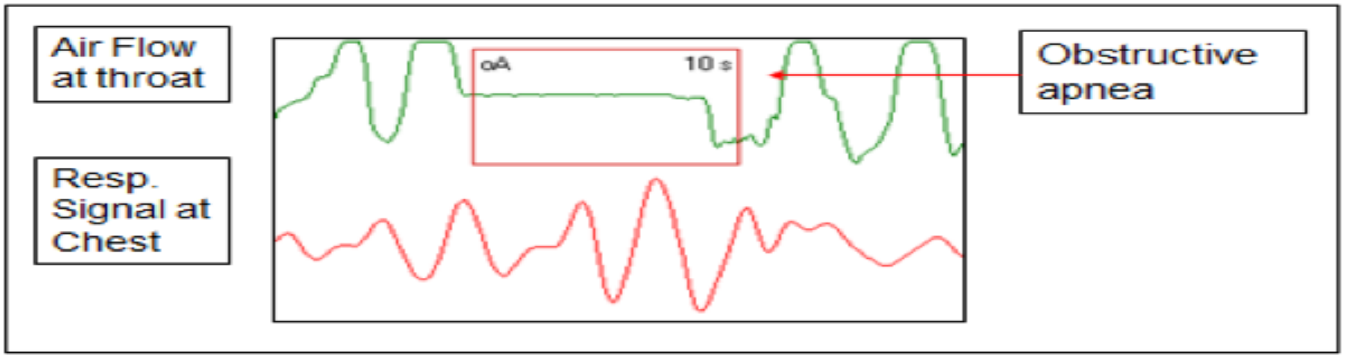
- Sleep apnea affect 2-4% of the middle-aged adult
- Potential Market : 7.5 Millions in UK & Ireland
- 80% are undiagnosed
- Untreated sleep apnea caused up to $3.4 billion additional medical cost in U.S. (2000)

Sleep apnea: different types

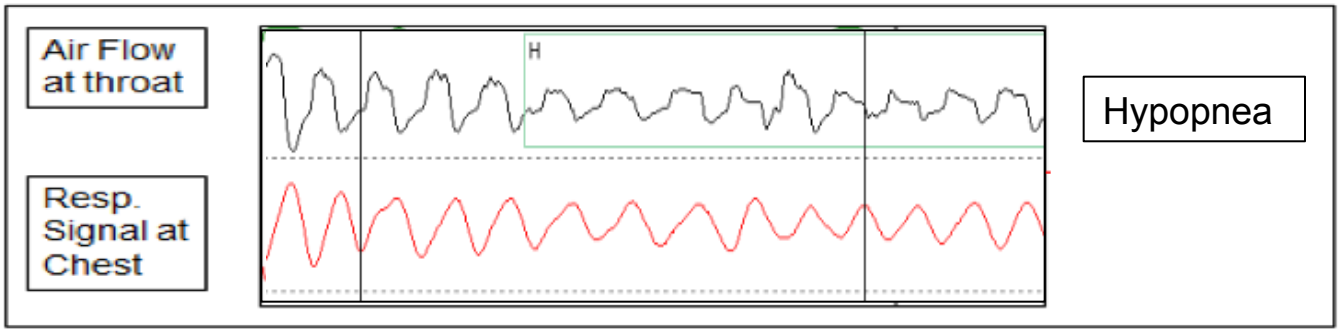
CSA



OSA



Hypopnea



Polysmnography (PSG): Gold standard

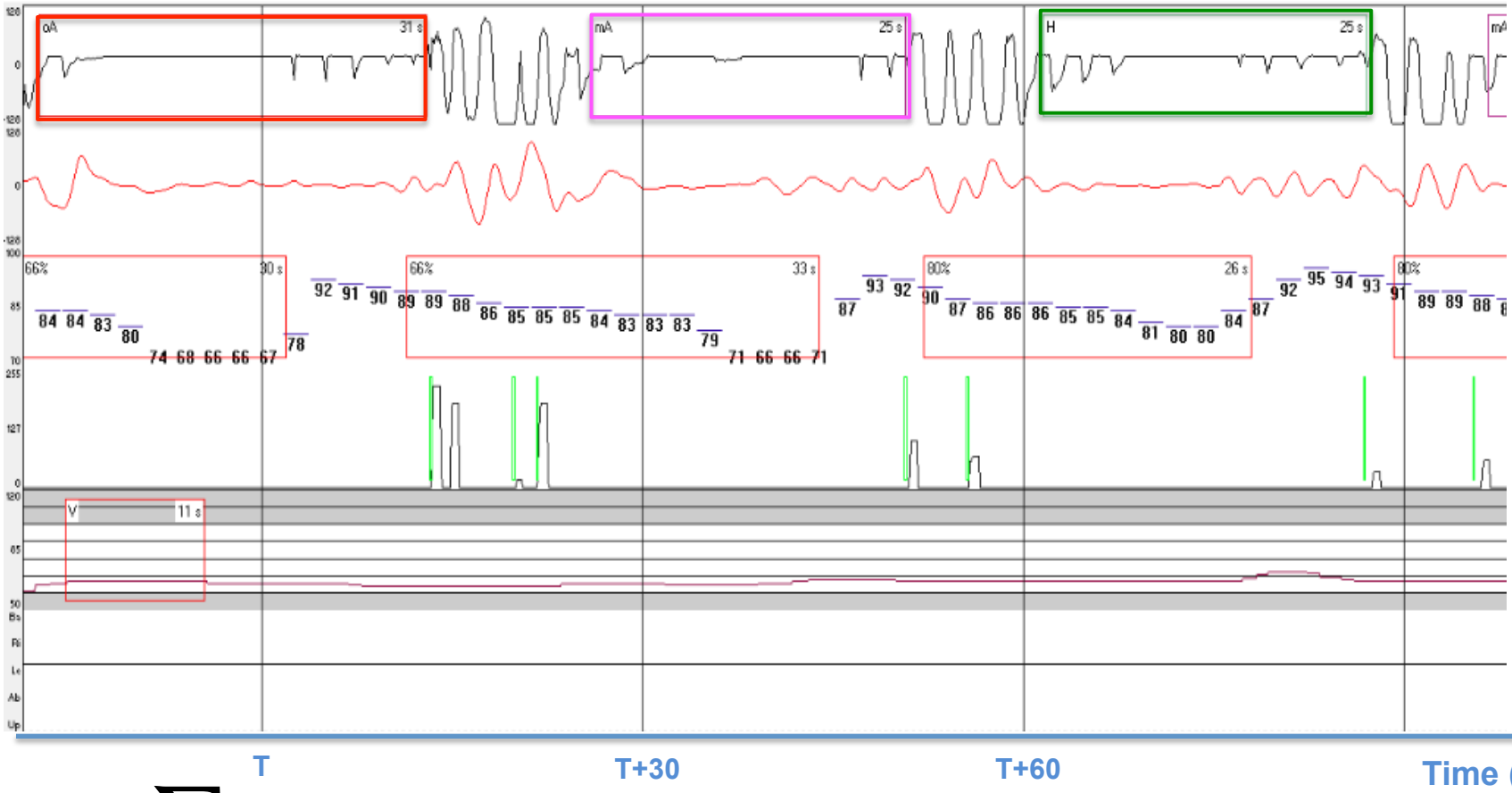
Resp. Band

Recording Device

Cannula measuring air flow and mic to record snoring

Pulse oximeter

PSG: Diagnostic



$$AHI = \frac{\sum apnea + hypopnea}{Time}$$

AHI < 5 ; No apnea

5<AHI <15 ; Minor apnea

15<AHI<30 ; Moderate apnea

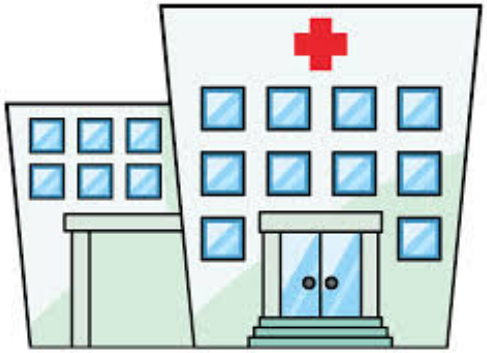
AHI >30 ; Severe apnea

PSG: limits and issues

Uncomfortable,
non natural sleep

Expensive,
1000€/night

Require overnight
stays at hospital



Long patient waiting list,
18 months

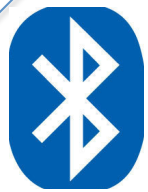
Proposed solution: homemade screening

...ZZZ
…zzz…

Microphone

- ECG
- Thorax Effort
- Position

Bluetooth



4G

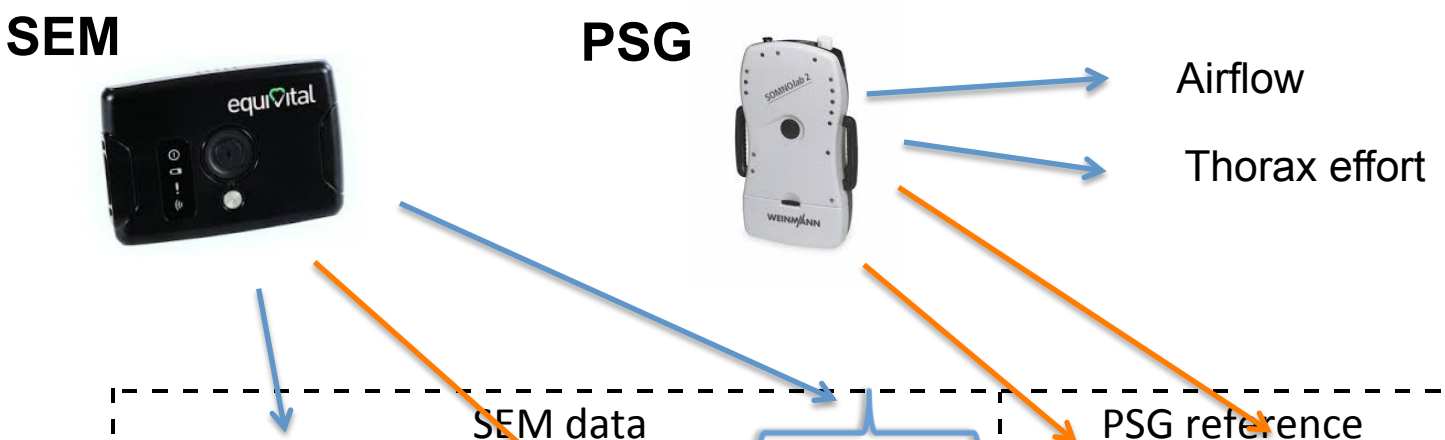
Cloud/
Clinic

Analysis, diagnostic, report generation

Device comparison

The clinical trials

- Run on 32 patients at Beaumont hospital
- Both devices were worn at the same time



		SEM data					PSG reference	
Data index	Time (sec)	Thorax Effort	SEMpos	Ax	Ay	Az	PSGpos	Apnea event
1	1	.	.	.	.	.	.	.
2	2	.	.	.	.	.	.	.
3	3	.	.	.	.	.	.	.
4	4	.	.	.	.	.	.	.
…	.	.	.	.	.	.	.	.

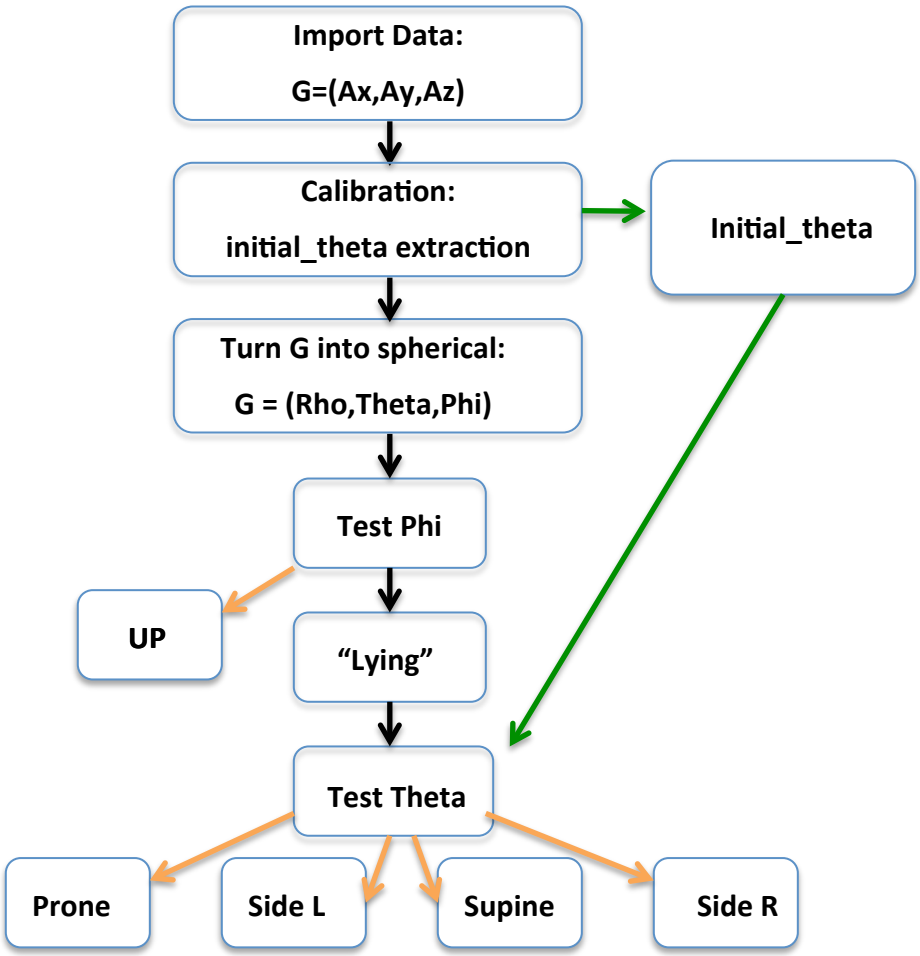
Part 1: Position diagnosis

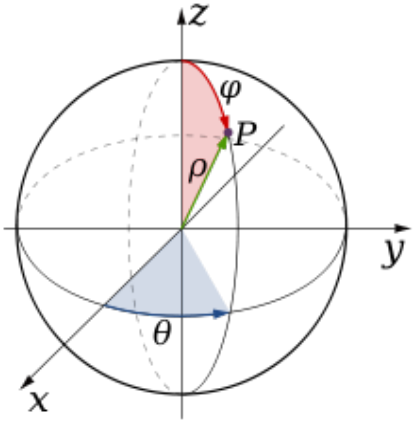
Initial results

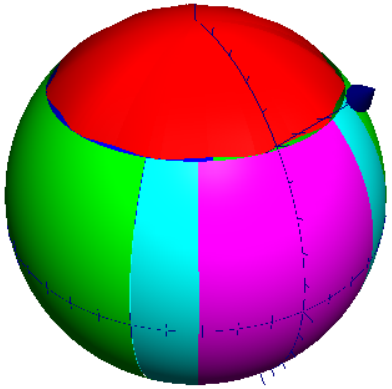
- 11% disparity between the two sensors
- Relative position between PSG and SEM may change during the night
- Relative position between the patient and devices may change during the night
- Taking in account the degree of comfort, PSG is more likely to move overnight than SEM
- However, the SEM position relative to patient may vary

Add a parameter called *Initial_theta* as the theta of the perfect supine position

Algorithm and Zones







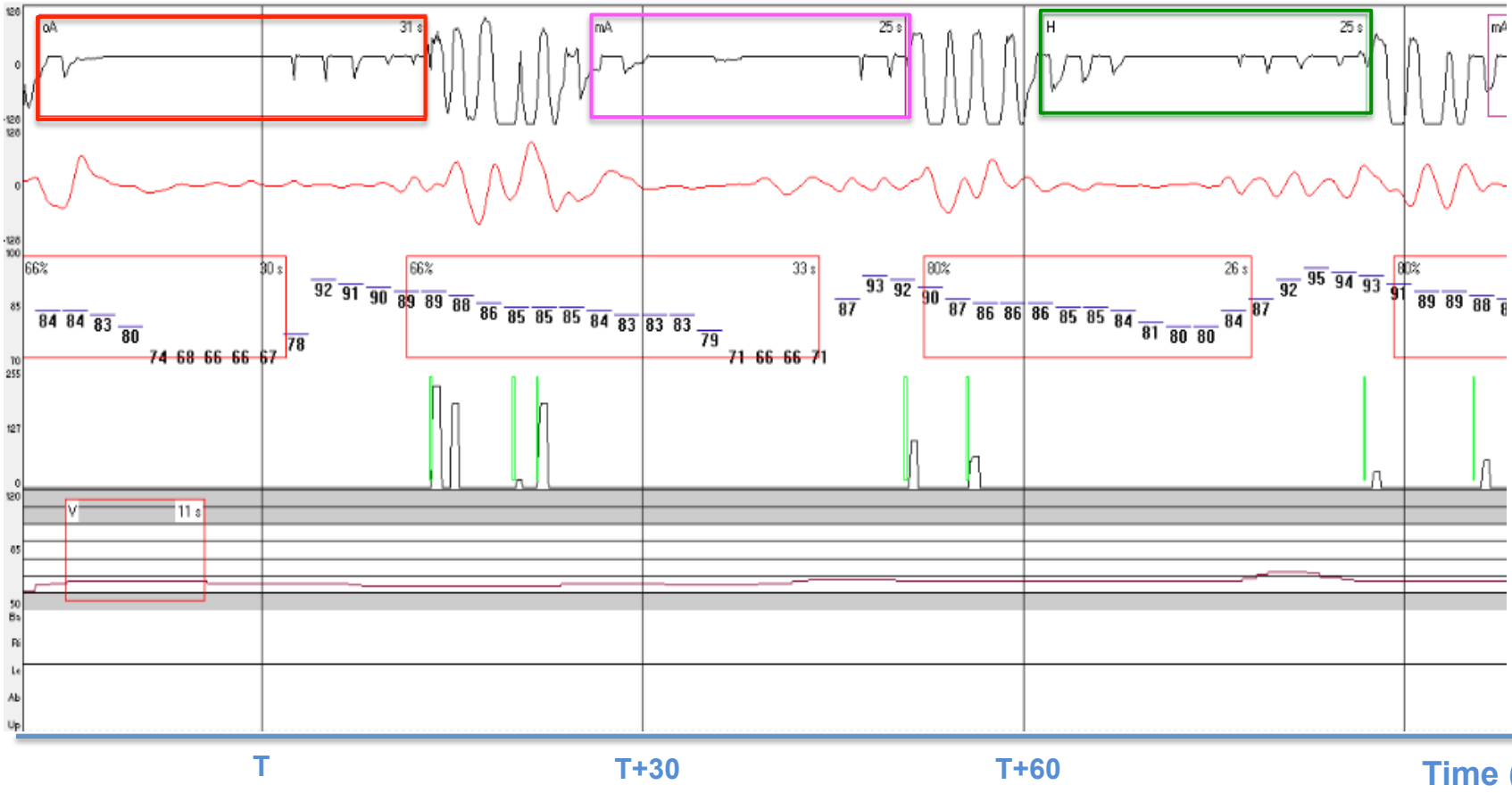
- Red : Upright
- Green: Left Side
- Yellow: Right Side
- Blue: Prone
- Magenta: Supine

Results of developed algorithm

- 95,9% matching results over 1,2 million of data points.
- Better diagnosis results with SEM compare to PSG.
- Further confirmation is needed i.e. video recording with IR camera to validate

Thorax effort Signal and diagnostic of apnea event

PSG apnea detection: How it works



$$AHI = \frac{Number\ of\ apnea + Hypopnea}{Time\ of\ the\ readable\ signal}$$

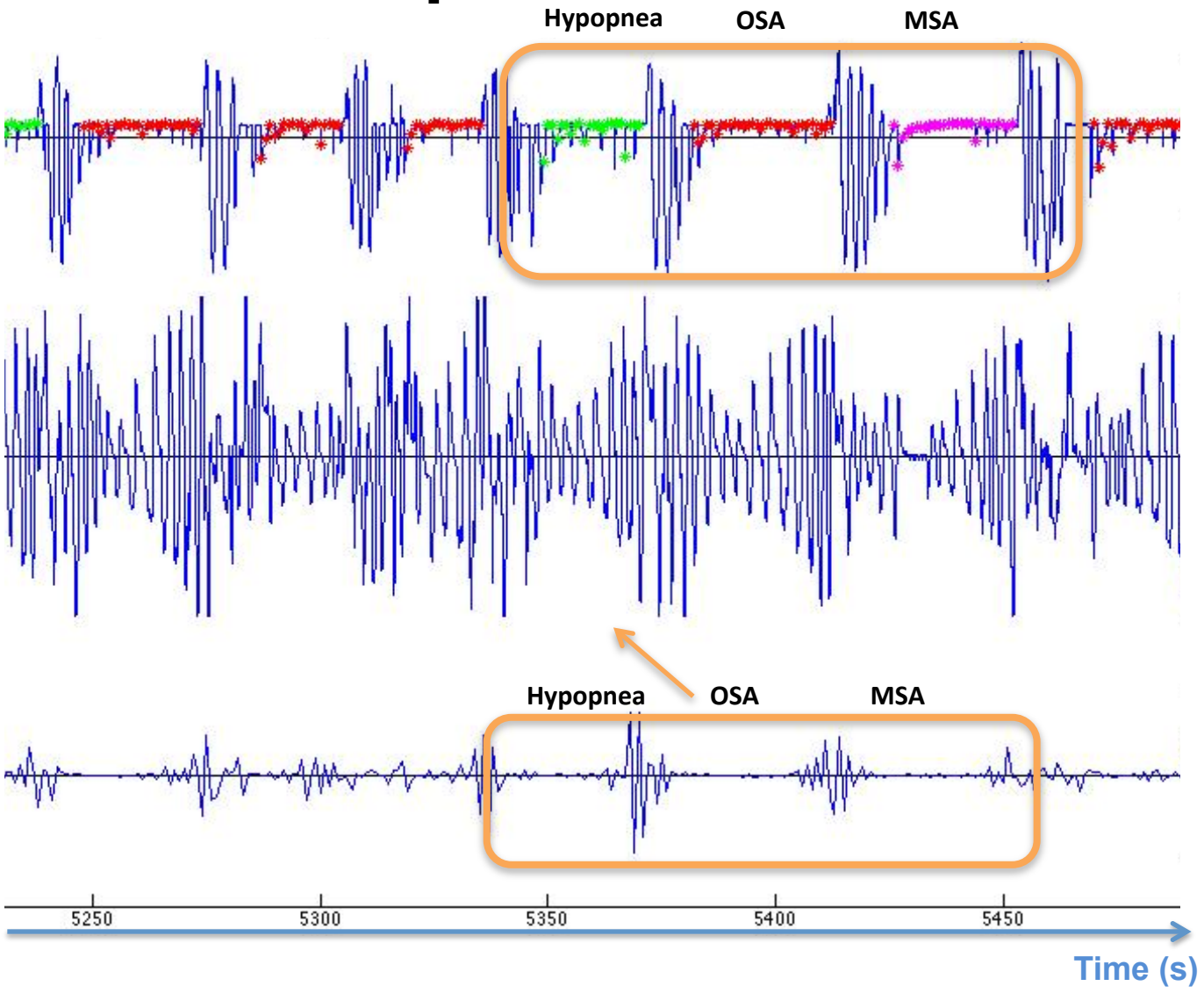
AHI < 5 ; No apnea
5<AHI <15 ; Minor apnea
15<AHI<30 ; Moderate apnea
AHI >30 ; Severe apnea

Apnea event: examples

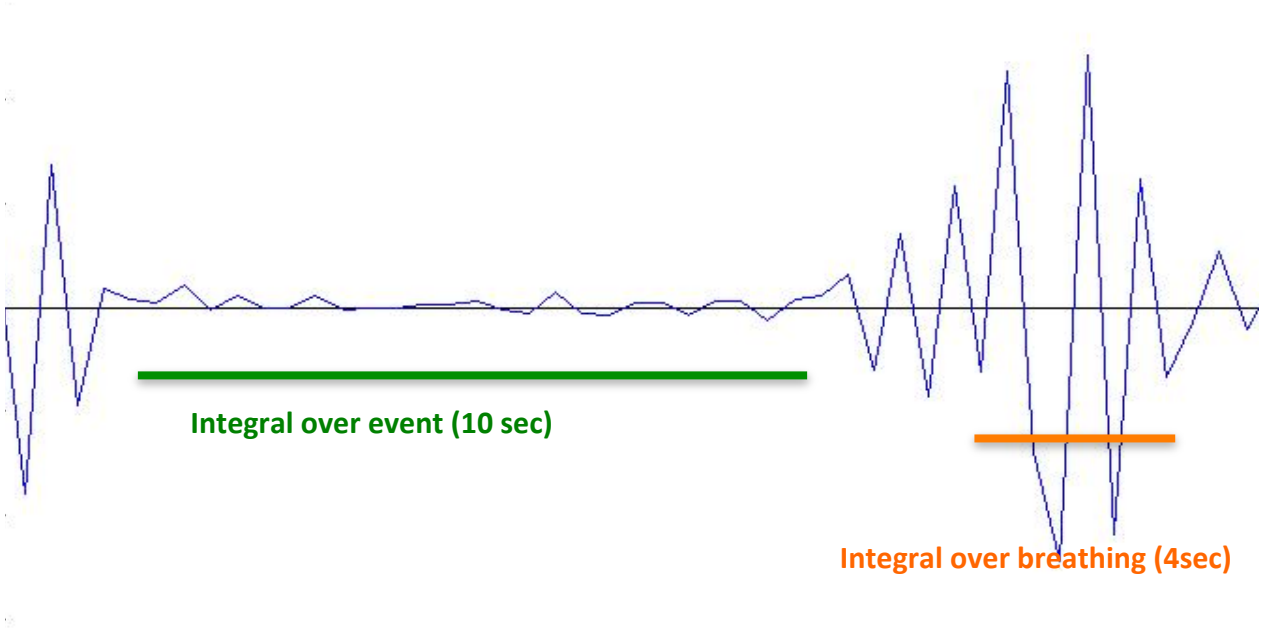
PSG: airflow

PSG: Thorax effort

SEM: Thorax effort



Apnea detection algorithm



If *Integral_10sec* < *Threshold*

and Position!=Up

Potential apnea event

If *Integral_10sec*Factor* <

max(*integral_4sec*)

Validation of the apnea event

Results (1)

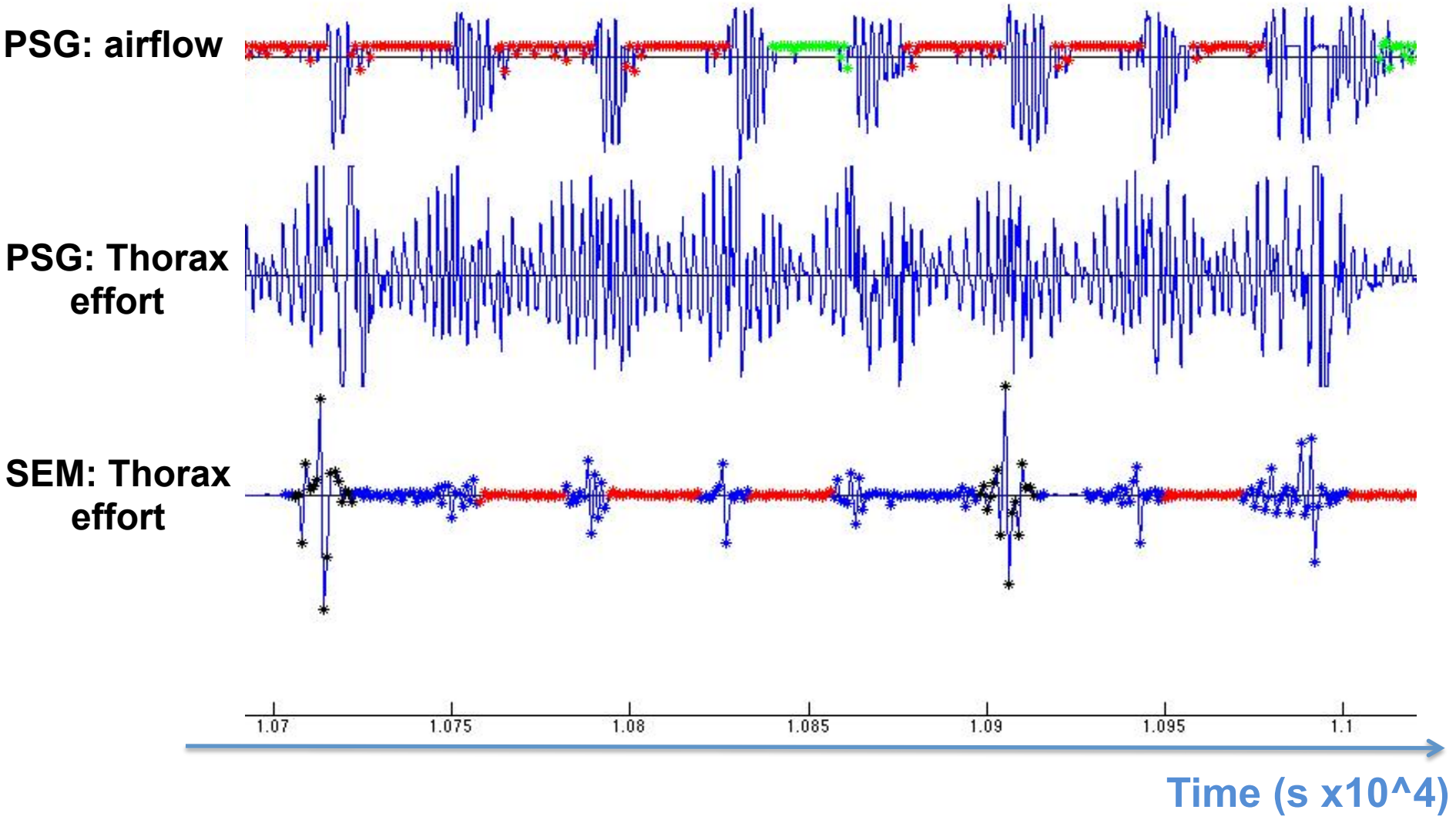
47% Matching

false positive = 109 %

Removing 3 people from the waiting list = 12%

Index	ID	Event found	Reference	Found that match	Found that are errors	Mean Value
1	13121001	19	6	0	19	2
2	13121102	99	37	20	79	1,77
3	13121600	28	8	1	27	1,2
4	14010707	96	38	3	93	0,664
5	14011500	241	63	43	198	1,39
6	14011601	155	137	101	54	1,38
7	14012000	179	6	1	178	0,91
8	14012200	141	38	23	118	1,24
9	14012700	3	27	2	1	2,7
10	14012801	48	0	0	48	1,46
11	14013000	107	90	30	77	1,08
12	14013101	158	356	131	27	2,84
13	14020302	74	164	29	45	0,86
14	14020603	92	98	50	42	1,67
15	14021000	177	44	27	150	0,77
16	14021101	118	2	0	118	0,83
17	14021202	120	71	23	97	0,86
18	14021302	80	117	25	55	1,99
19	14021701	394	521	367	27	2,38
20	14021801	230	29	18	212	1,29
21	14021902	176	105	34	142	0,95
22	14022001	326	157	88	238	1,11
23	14022400	101	9	4	97	1,9
24	14022501	78	19	2	76	0,91
25	14022601	124	6	1	123	1,1
	Total	3364	2148	1023	2341	

Patient number 19



Results (2)- personalized algorithm

43% Matching

false positive = 55 %

Removing 7 people from the waiting list = 28%

Index	ID	Event found	Reference	Found that match	Found that are errors	Mean Value
1	13121001	16	6	0	16	2
2	13121102	52	37	14	38	1,77
3	13121600	24	8	1	23	1,2
4	14010707	103	38	10	93	0,664
5	14011500	81	63	21	60	1,39
6	14011601	127	137	96	31	1,38
7	14012000	80	6	2	78	0,91
8	14012200	93	38	33	60	1,24
9	14012700	5	27	2	3	2,7
10	14012801	21	0	0	21	1,46
11	14013000	78	90	33	45	1,08
12	14013101	163	356	131	32	2,84
13	14020302	23	164	15	8	0,86
14	14020603	71	98	45	26	1,67
15	14021000	22	44	8	14	0,77
16	14021101	72	2	1	71	0,83
17	14021202	149	71	27	122	0,86
18	14021302	44	117	12	32	1,99
19	14021701	374	521	347	27	2,38
20	14021801	126	29	16	110	1,29
21	14021902	61	105	15	46	0,95
22	14022001	186	157	74	112	1,11
23	14022400	37	9	1	36	1,9
24	14022501	46	19	5	41	0,91
25	14022601	43	6	1	42	1,1
	Total	2097	2148	910	1187	

Conclusion

- Position diagnosis algorithm 95,9%
- Sleep apnea event diagnosis 43%
- Reduction waiting list ≈ 28%
- Limited results with Hypopnea
- Marge of improvement still possible
- Crosslinking this work with the work on the microphone and ECG will give more accurate results

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Thanks for the attention

Questions?