서울아산병원
Asan Medical Center

울산대학교 의과대학
UNIVERSITY OF ULSAN COLLEGE OF MEDICINE

Holter monitoring의 적응증과 해석

Myung-Jin Cha, M.D., Ph.D.
Clinical assistant professor
Cardiology (Cardiac electrophysiology)
Asan Medical Center, Seoul, South Korea

New Method for Heart Studies

Continuous electrocardiography of active subjects over long periods is now practical.

Norman J. Holter

Electrocardiography today is an indispensable tool for physiologist and physician. Cardiac electrophysiology began in 1887 when Ludwig and Waller first noted changing chest potentials, and practical electrocardiography began in 1893 with Einthoven's string galvanometer work. Then followed the body of classic work in this field, but the electrocardiograph did not find wide use until the advent of modern direct-writing instruments. Today's clinical instrument is convenient and dependable and will remain an important tool in research and in examinations of established heart conditions. It is still only a hit-or-miss affair for studying long-period heart action or detecting transient heart aberrations.

Until recently, electrocardiography required connecting leads from subject to instrument. This was no handicap in building present-day principles but has been a handicap in studying active subjects. Leads can be detached during exercise and reconnected later, and with special electrodes some exercise is feasible during recording. However, considerably more physical freedom is desirable if one is to learn more about the heart under realistic conditions of daily life.

This article reports a series of concepts and developments concerned with obtaining long-period continuous electrocardiographic records from active subjects in order to obtain data which constitute a statistically valid sample of heart action under conditions that give the subject the greatest possible freedom of activity. This goal automatically generates the problem of handling, in a convenient and practical way, the very voluminous data acquired. No one can adequately examine 100,000 continuous ordinary electrocardiograms (24-hour recording at a pulse rate of 70). A number of early ideas have led to the concept of breaking away from the limitations of orthodox electrocardiography to solve the scientific problem of adequate sampling and the medical problem of obtaining electrocardiograms in situations other than the highly artificial and unrealistic situation of resting quietly on a comfortable pad after a good sleep, with no breakfast, and with calm confidence in one's physician.

In 1939 J. A. Gengerelli and I became interested in remote stimulation of physiological systems as means for minimizing interference with the system. By modifying a classic experiment, we produced contractions of frog muscle by stimulating its nerve supply by means of a changing electric field without electrodes or connecting wires (*1*). This raised the converse question of whether an external field is created by a nerve impulse. From these two basic and converse ideas developed a series of studies leading, on the one hand, to the remote stimulation of the brain of the intact animal and a study of corresponding behavior (*2*, *3*) and, on the other hand, to the use of radio for the accurate transmission of electroencephalograms and electrocardiograms from freely exercising subjects (*4*, *5*). With the electronics of 1942, a nerve impulse field was not detected (*2*), but recently we obtained evidence for the existence of such a field (*6*). Radioelectrocardiography as a practical and convenient technique is now becoming relatively routine; its first clinical application was by MacInnis in 1954 (*7*).

Steps toward Freedom

Up to this point there has been developed only what I would call an initial step toward freedom—the elimination of entangling wires. Moreover, while telemetering per se does provide greater freedom of action, it does not provide practical long-period continuous electrocardiography. It also requires an in-

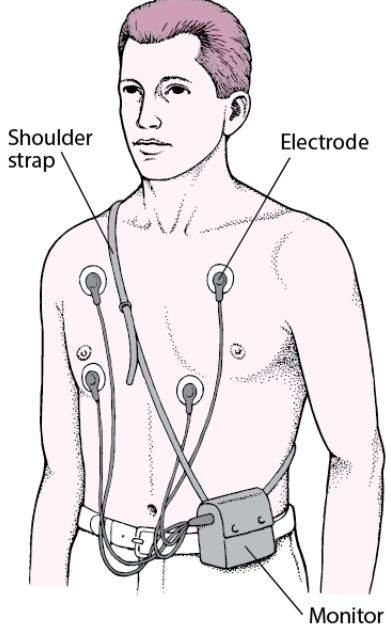
The author is president of the Holter Research Foundation, Helena, Montana. This article is based on a paper presented 20 July 1961 at the 4th International Conference on Medical Electronics, New York.

Holter monitoring

First introduced by the American biophysicist Norman J. Holter (1914–1983) in the 1940s

https://www.jstor.org/stable/1707823

Holter monitoring



- Small recorders (size, 70×95×20 mm; weight, ≈190 g) with flashcard technology to record and store data
- Multiple ECG leads attached to the patient's chest
- Collected continuously over 24 to 48 hours
- Analyzed in digital format
- Asked to keep a diary of their symptoms
- Patient-activated event markers (annotations)

- ➢ Ability to continuously record ECG data
- ➢ No need in the transmission of data
- ➢ Short duration of monitoring can be inadequate

Circulation, 2010 Oct 19;122(16):1629-36.

Holter Monitoring 적응증

요양급여 인정기준이 있지는 않으나

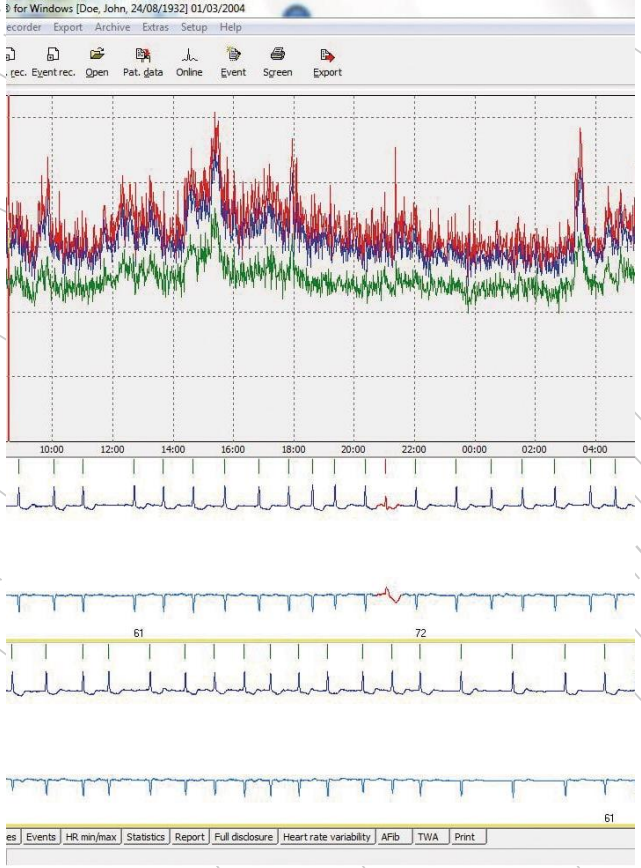
심평원에서 제시하고 있는 적응증으로는 아래와 같음

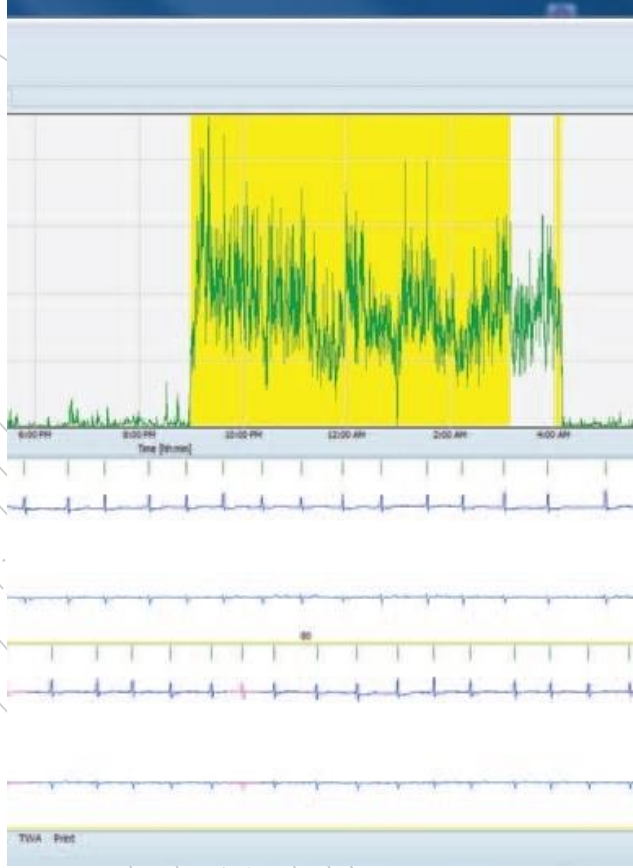
- 1. 상심실성 부정맥
- 2. 심실성 부정맥
- 3. 기외수축
- 4. 동기능 부전 증후군
- 5. 방실 차단
- 6. 허혈성 심질환
- 7. 인공 심박조율기 기능 판정
- 8. 부정맥과 일상생활과의 연관성 판정
- 9. 부정맥 치료 효과의 판정

상기 상병 및 R/O 상병 또는 심혈관계 증상(chest pain, palpitation, syncope, dyspnea 등) 관련 상병시 인정되고 있음

24시간 홀터기록 검사후 판독(Monitoring data analysis & evaluation) 및 Heart Rate Variability Analysis : 24시간 홀터기록검사의 소정점수에 포함됨

Different types of Holter monitoring





Holter monitoring analysis system

[redacted]

Hookup Date: **07-Sep-2021**
Hookup Time: **15:49:00**
Duration: **22:46:00**
Recorder Serial #: [redacted]
Order #:

General

91822 QRS complexes
0 Paced beats (< 1%)
76 Ventricular beats (< 1%)
22 Supraventricular beats (< 1%)
0 BB beats (< 1%)
0 Junctional beats (< 1%)
0 Aberrant beats
0 % of total time in AF/AFL
7 % of total time classified as noise

Heart Rates

56 Minimum at 05:56:04 08-Sep
72 Average
114 Maximum at 16:54:25 07-Sep
1163 Beats in tachycardia (>=100 bpm), 1% total
4585 Beats in bradycardia (<=60 bpm), 5% total
1.22 Seconds Max R-R at 04:09:27 08-Sep

Ventriculars (V, F, E, I)

76 Isolated
0 Couplets
0 Bigeminal cycles
0 Runs totaling 0 beats

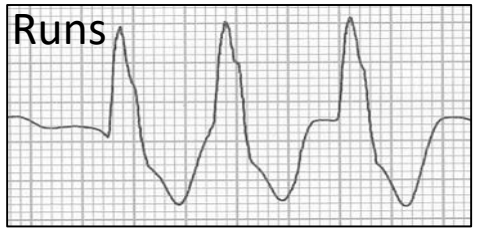
Supraventriculars (S, J, A)

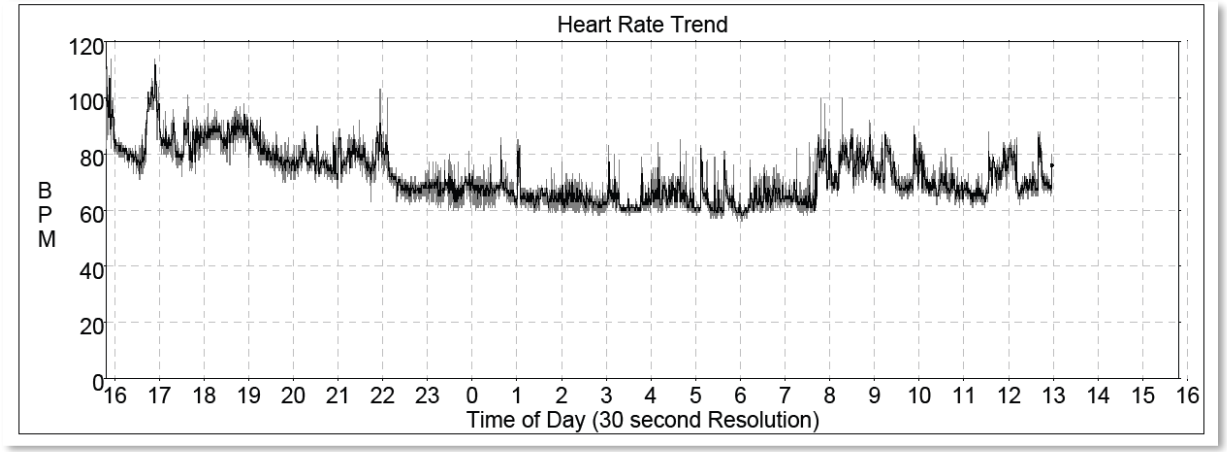
15 Isolated
2 Couplets
0 Bigeminal cycles
1 Runs totaling 3 beats
3 Beats longest run 140 bpm 22:06:15 07-Sep
3 Beats fastest run 140 bpm 22:06:15 07-Sep

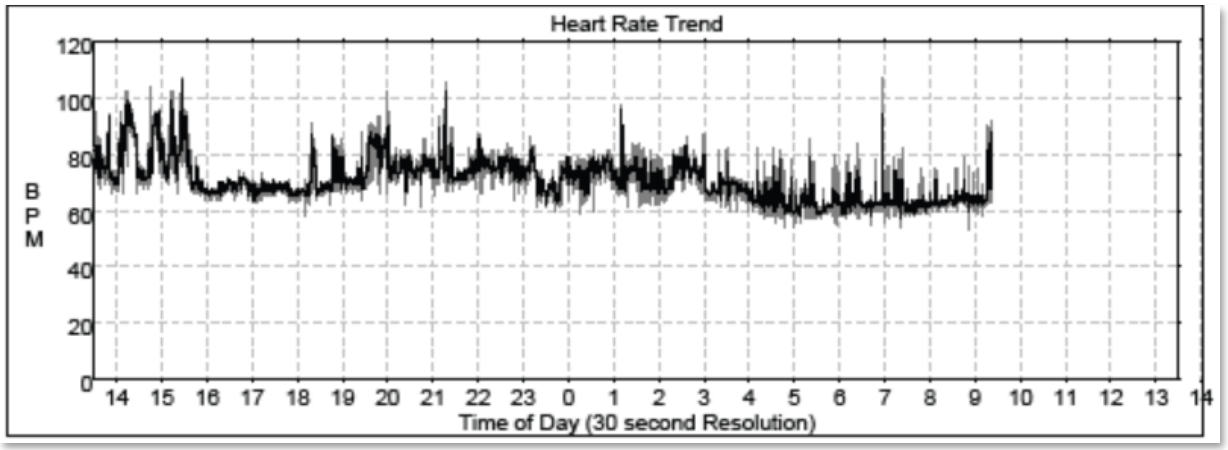
Hourly Summary

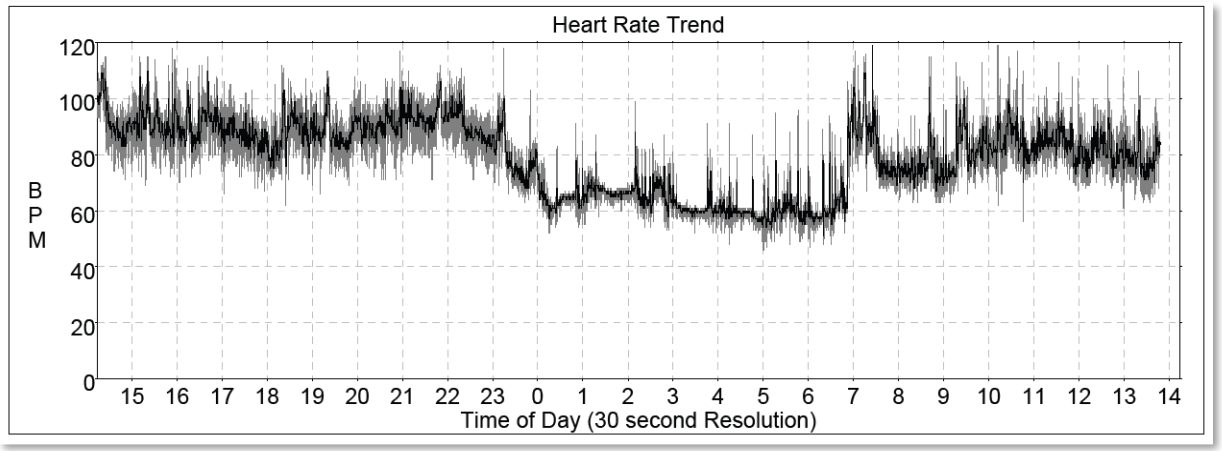
*RR Pause Criteria: 2000

		Heart Rate					Ventricular					Supraventricular				
Hour	Min.s Used	#QRS's	Min.	Ave.	Max.	Pauses	Iso	Cplt	Runs	Max Run	Max Rate	Iso	Cplt	Runs	Max Run	Max Rate
15	11	1047	81	96	114	0	3	0	0	0	0	4	1	0	0	0
16	60	5141	71	86	114	0	8	0	0	0	0	1	0	0	0	0
17	60	5043	72	84	101	0	15	0	0	0	0	2	0	0	0	0
18	60	5276	76	88	98	0	13	0	0	0	0	1	0	0	0	0
19	60	4841	70	81	93	0	9	0	0	0	0	0	0	0	0	0
20	60	4634	68	77	90	0	9	0	0	0	0	0	0	0	0	0
21	60	4749	63	79	103	0	7	0	0	0	0	3	0	0	0	0
22	60	4219	62	70	100	0	0	0	0	0	0	0	0	1	3	140
23	60	4096	60	68	81	0	0	0	0	0	0	0	0	0	0	0
00	60	4050	60	68	86	0	0	0	0	0	0	0	0	0	0	0
01	60	3918	59	65	85	0	0	0	0	0	0	0	0	0	0	0
02	60	3834	58	64	77	0	0	0	0	0	0	0	0	0	0	0
03	60	3780	58	63	83	0	0	0	0	0	0	1	0	0	0	0
04	60	3933	59	66	85	0	0	0	0	0	0	1	1	0	0	0
05	60	3789	56	63	83	0	0	0	0	0	0	0	0	0	0	0
06	60	3834	56	64	78	0	0	0	0	0	0	0	0	0	0	0
07	60	4101	58	68	100	0	2	0	0	0	0	1	0	0	0	0
08	60	4617	65	77	100	0	6	0	0	0	0	0	0	0	0	0
09	60	4387	64	73	90	0	0	0	0	0	0	0	0	0	0	0
10	60	4151	61	69	84	0	1	0	0	0	0	0	0	0	0	0
11	60	4206	61	70	88	0	0	0	0	0	0	1	0	0	0	0
12	58	4176	62	72	88	0	3	0	0	0	0	0	0	0	0	0
13	0	0	---	---	---	0	0	0	0	0	0	0	0	0	0	0
14	0	0	---	---	---	0	0	0	0	0	0	0	0	0	0	0
	1269	91822	56	72	114	0	76	0	0	0	0	15	2	1	3	140

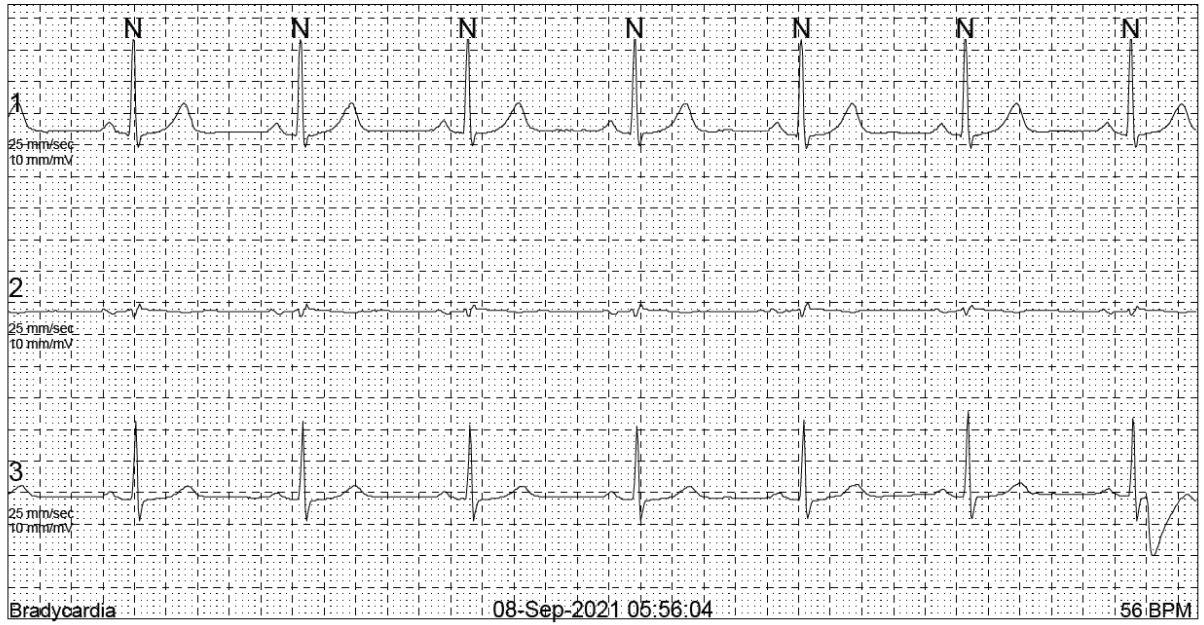




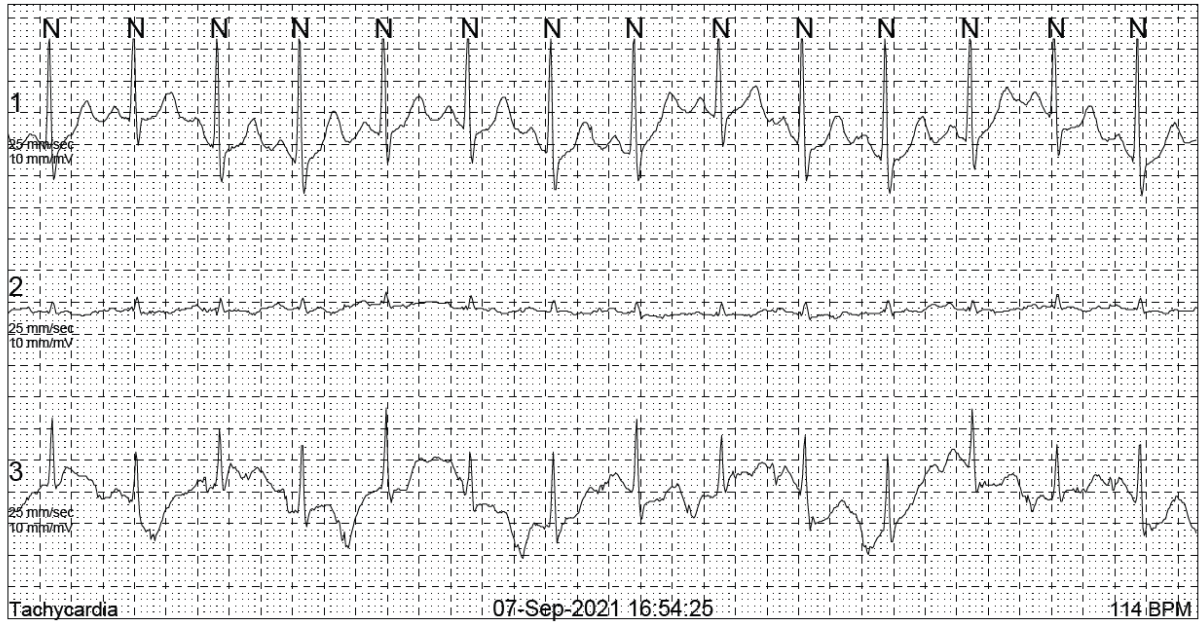


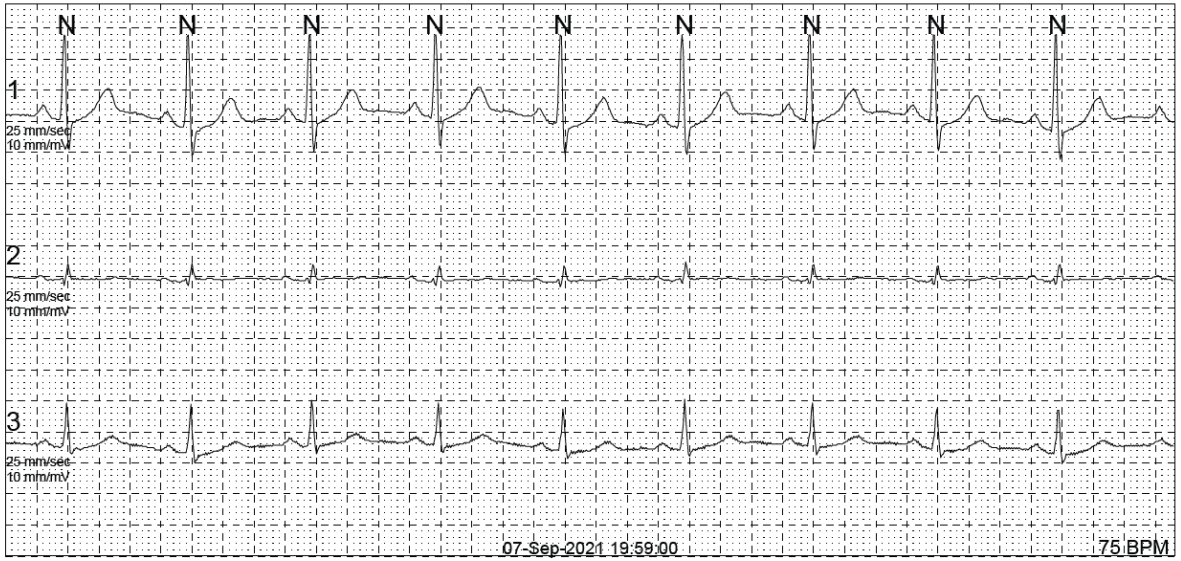


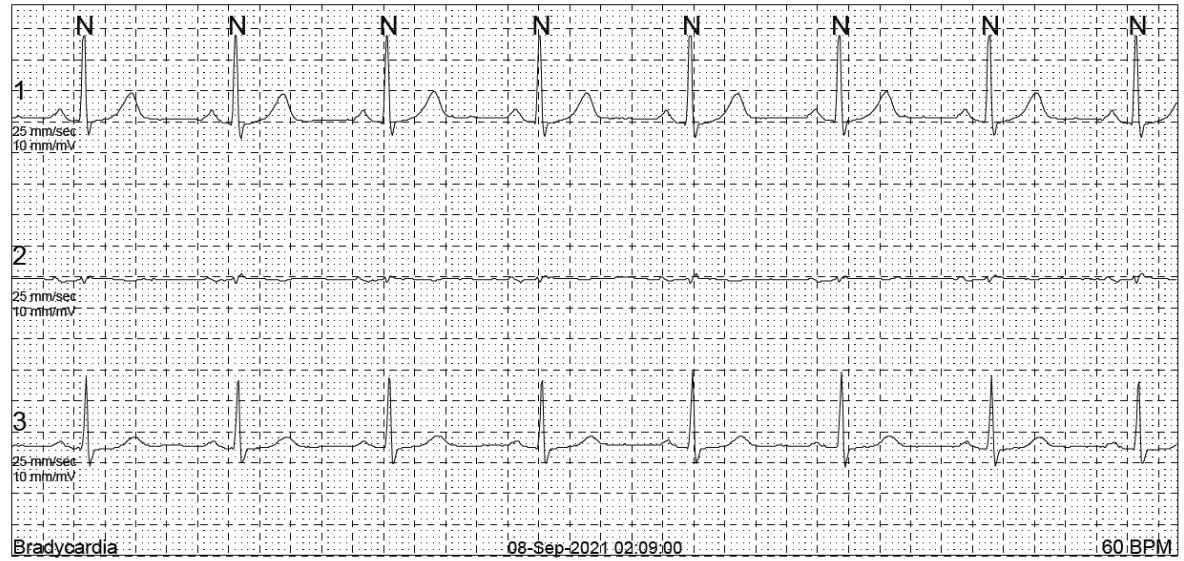
Min Heart Rate

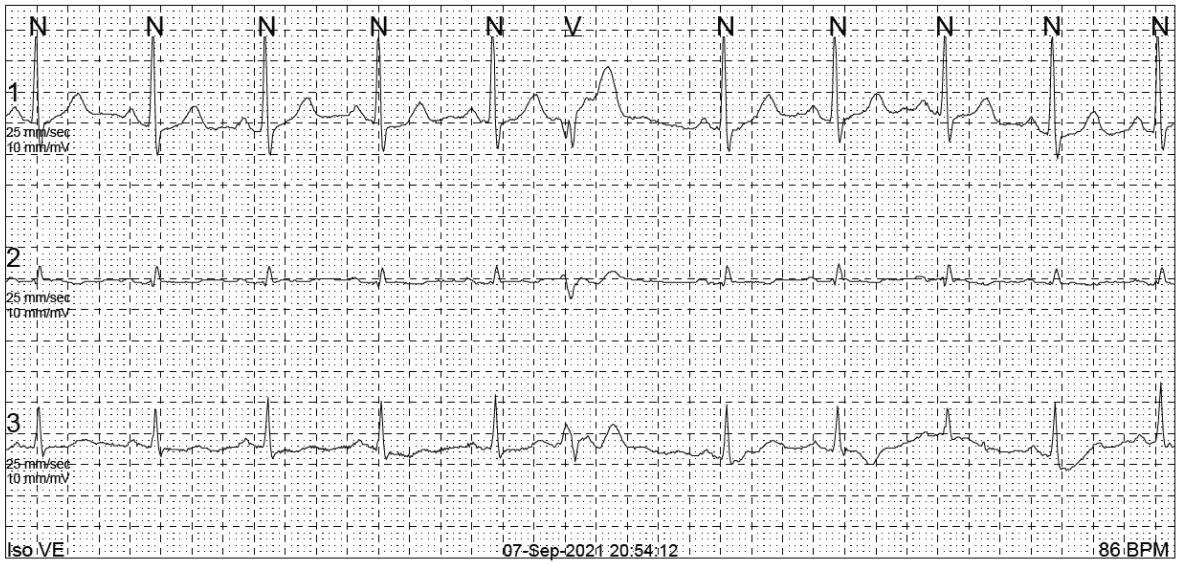


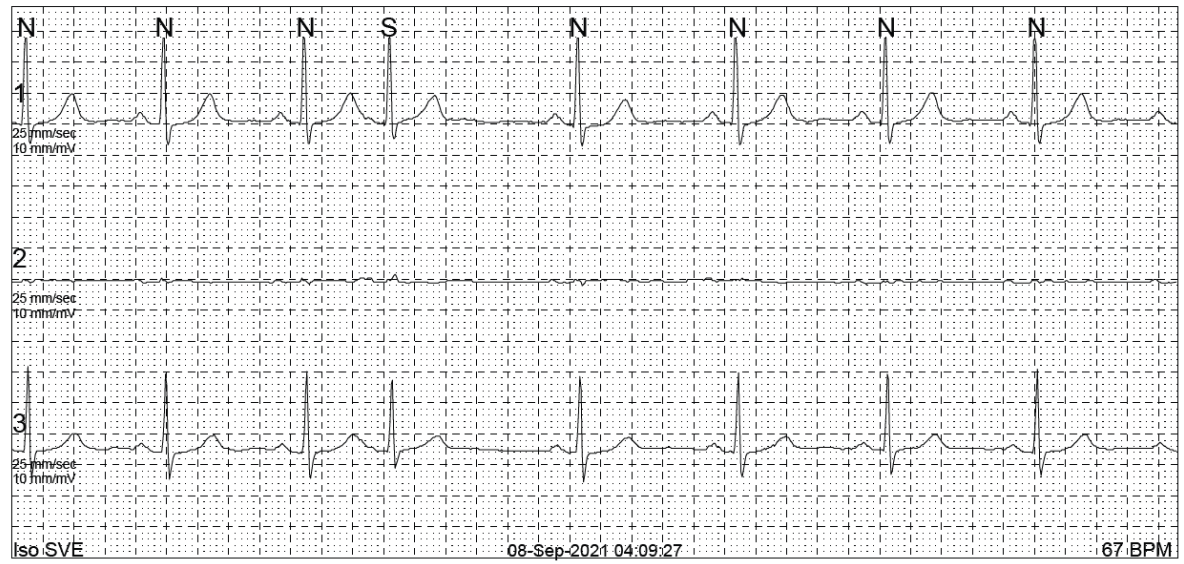
Max Heart Rate



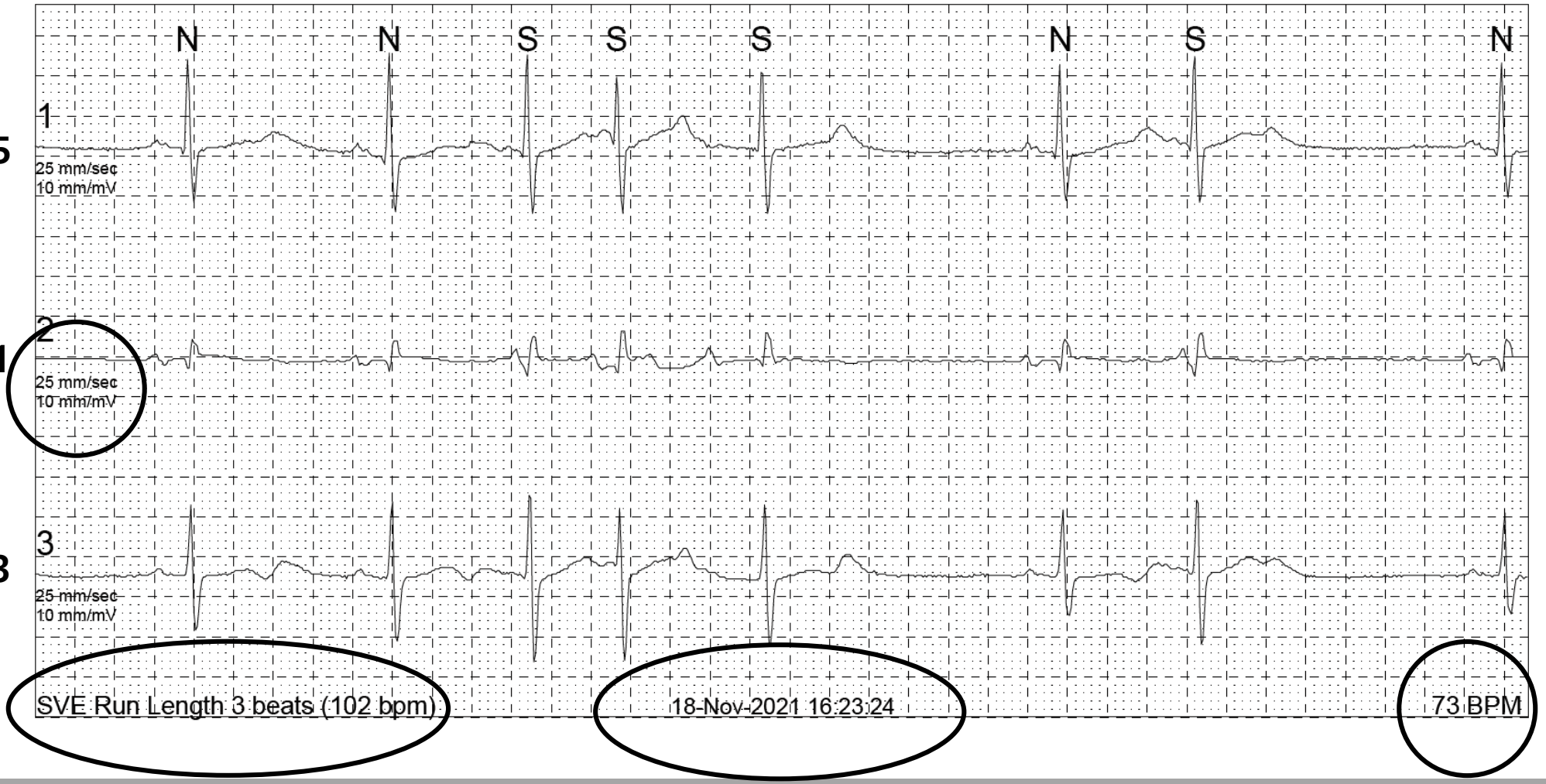

N N N N N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
07-Sep-2021 19:59:00
75 BPM


N N N N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Bradycardia
08-Sep-2021 02:09:00
60 BPM

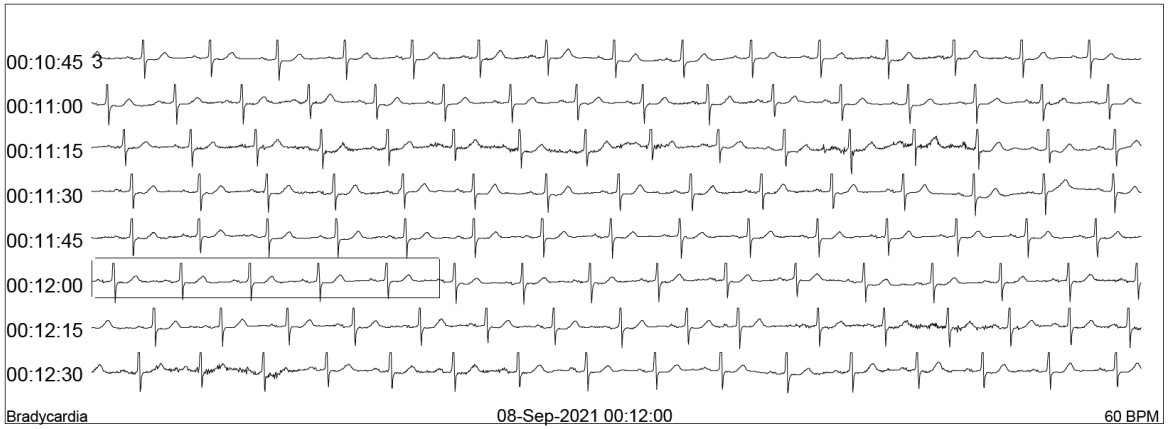

N N N N N V N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Iso VE
07-Sep-2021 20:54:12
86 BPM


N N N S N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Iso SVE
08-Sep-2021 04:09:27
67 BPM

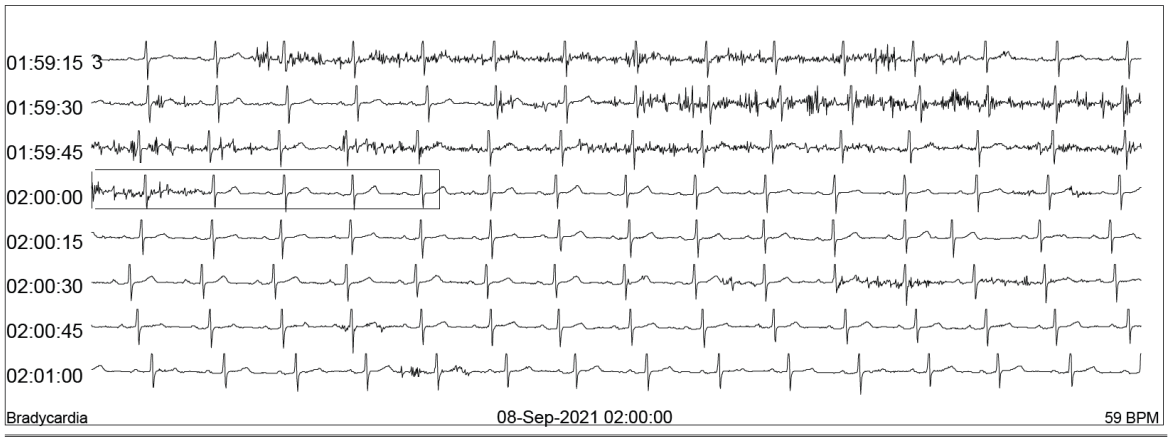
25mm/sec
10mm/mV



DYSPNEA

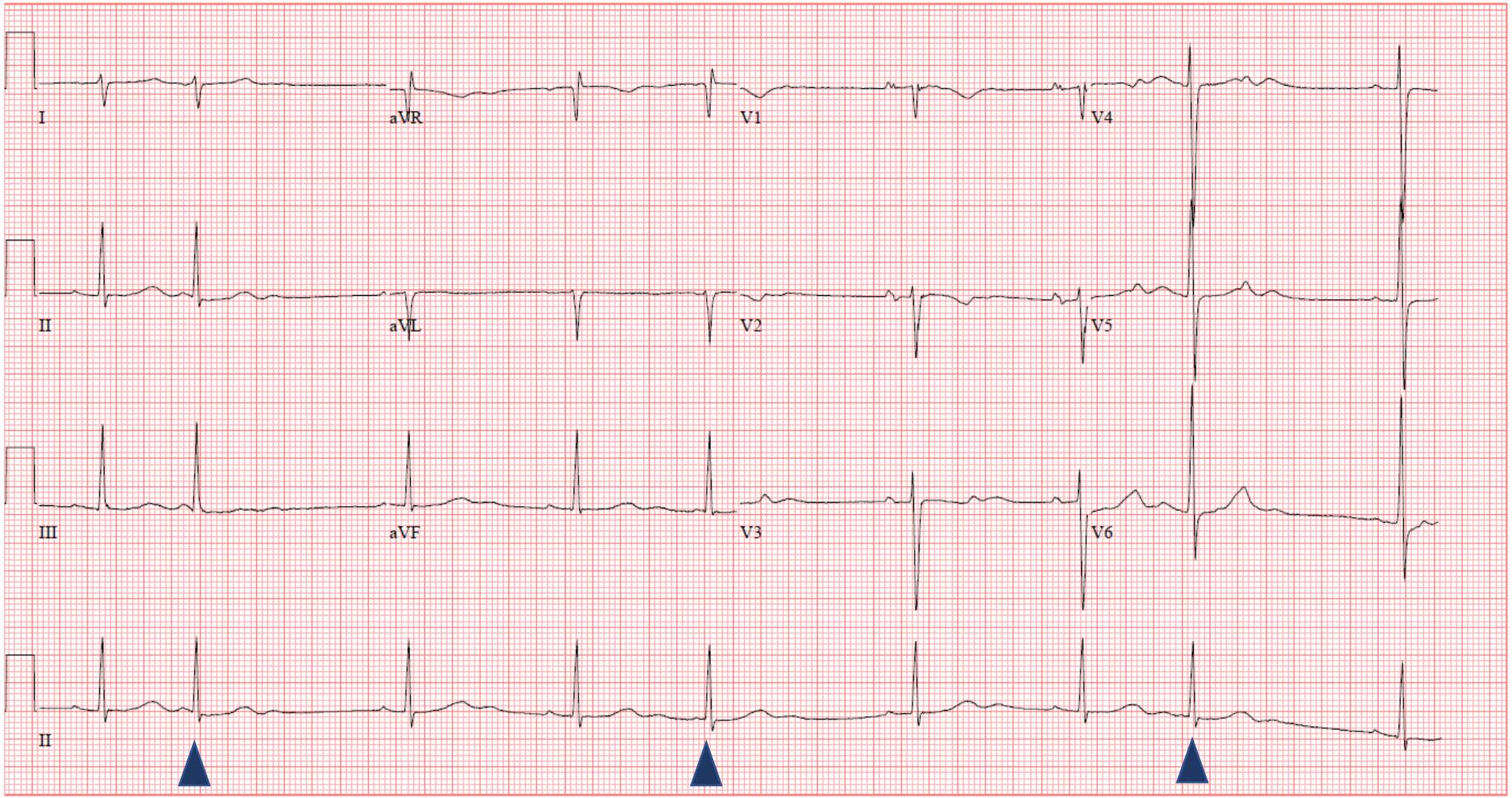


CHEST DISCOMFORT



Case 1

- F/56, intermittent dizziness



General

101483	QRS complexes
0	Paced beats (< 1%)
0	Ventricular beats (< 1%)
3076	Supraventricular beats (3%)
0	BB beats (< 1%)
0	Junctional beats (< 1%)
2102	Aberrant beats
94	% of total time in AF/AFL
< 1	% of total time classified as noise

Ventriculars (V, F, E, I)

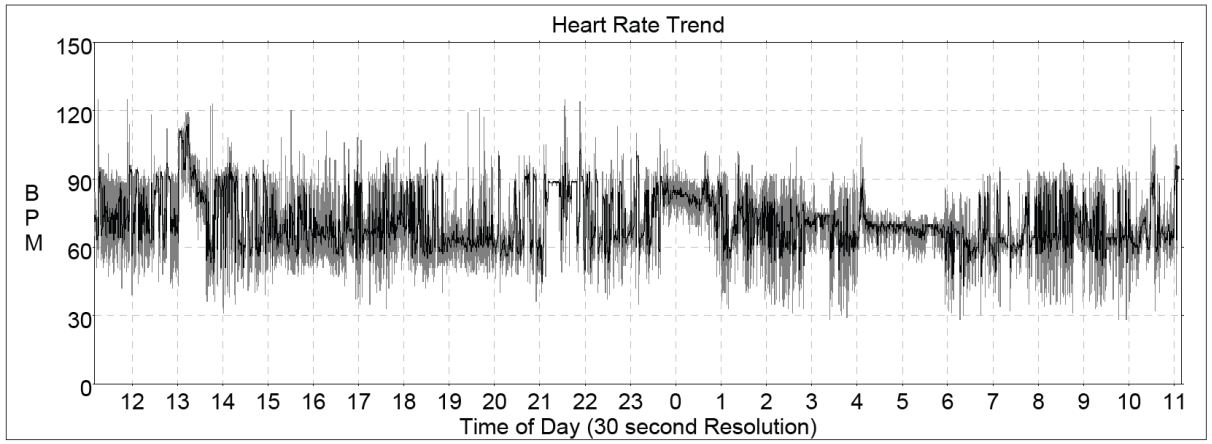
0	Isolated
0	Couplets
0	Bigeminal cycles
0	Runs totaling 0 beats

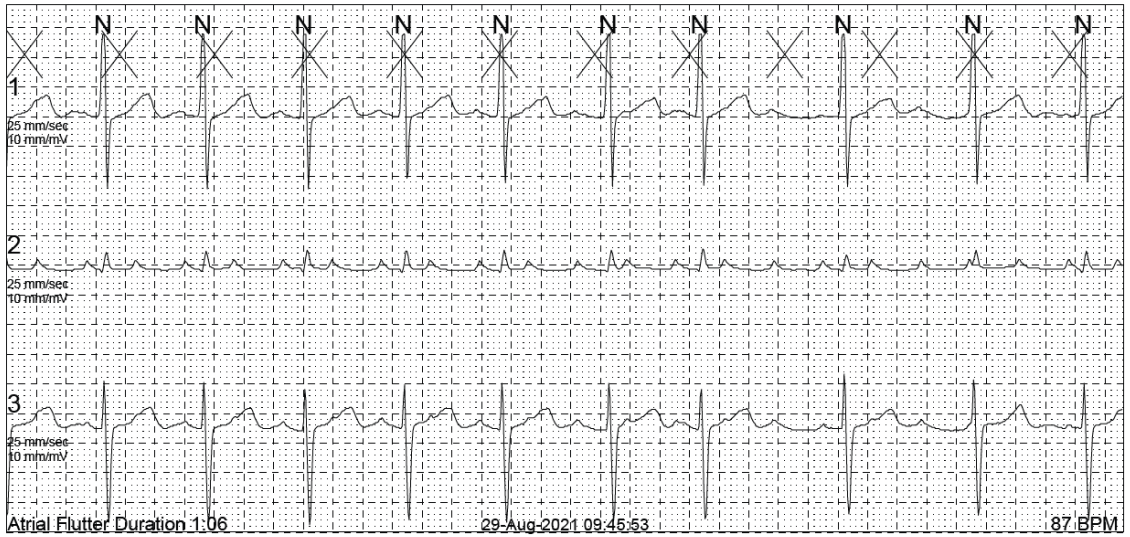
Heart Rates

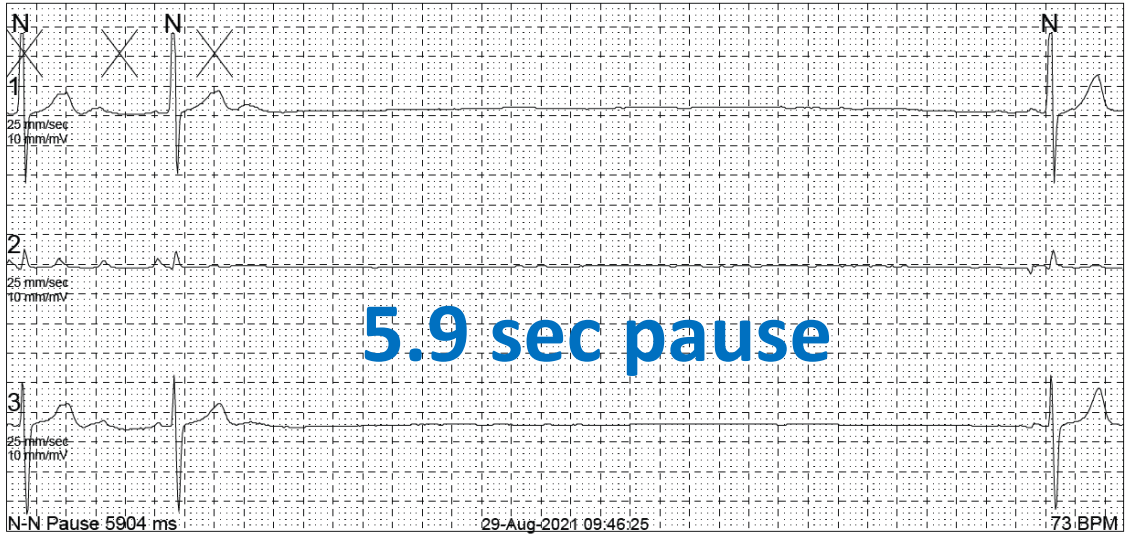
28	Minimum at 03:23:38 29-Aug
71	Average
125	Maximum at 21:33:41 28-Aug
2165	Beats in tachycardia (>=100 bpm), 2% total
18902	Beats in bradycardia (<=60 bpm), 19% total
5.93	Seconds Max R-R at 03:23:33 29-Aug

Supraventriculars (S, J, A)

2693	Isolated
111	Couplets
1291	Bigeminal cycles
42	Runs totaling 160 beats
7	Beats longest run 112 bpm 22:42:39 28-Aug
4	Beats fastest run 113 bpm 11:28:19 28-Aug

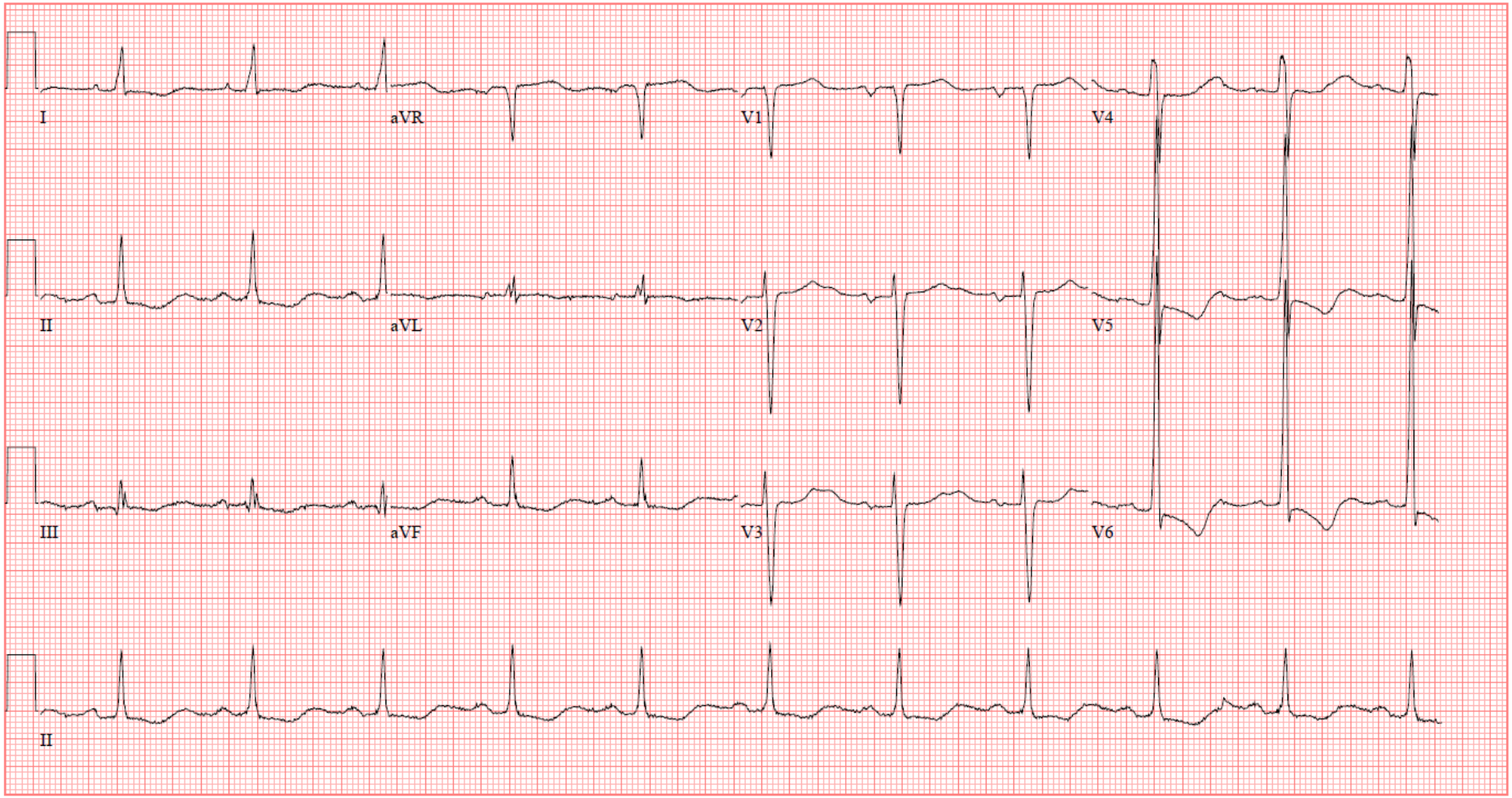






Case 2

- F/67 with dizziness and palpitation



General

111250	QRS complexes
0	Paced beats (< 1%)
34749	Ventricular beats (31%)
0	Supraventricular beats (< 1%)
0	BB beats (< 1%)
0	Junctional beats (< 1%)
0	Aberrant beats
0	% of total time in AF/AFL
4	% of total time classified as noise

Ventriculars (V, F, E, I)

6684	Isolated
761	Couplets
123	Bigeminal cycles
815	Runs totaling 26531 beats
2057	Beats longest run 167 bpm 12:54:17 18-Nov
4	Beats fastest run 225 bpm 02:53:21 19-Nov

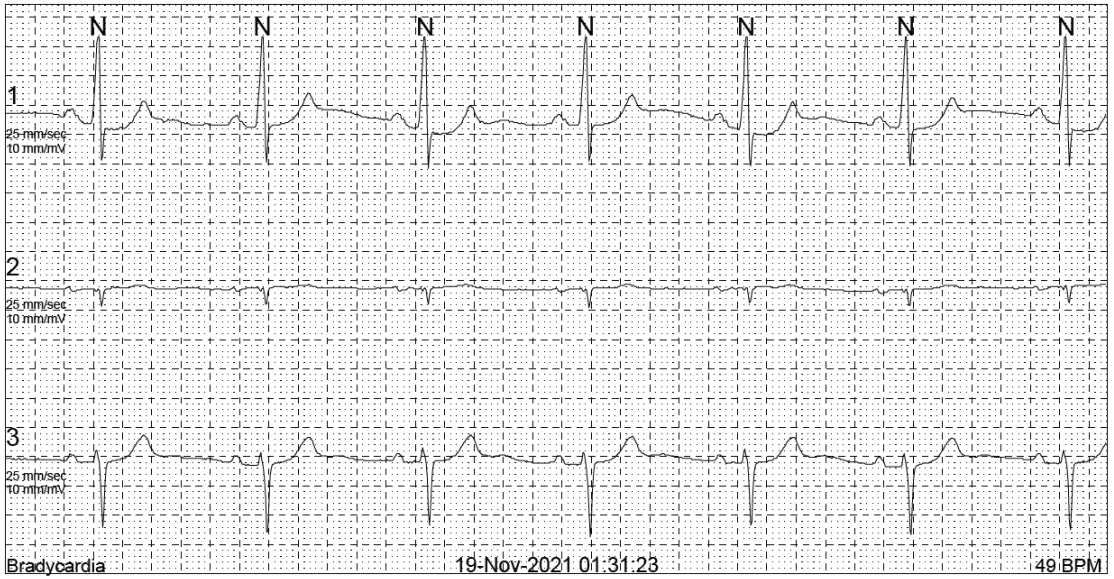
Heart Rates

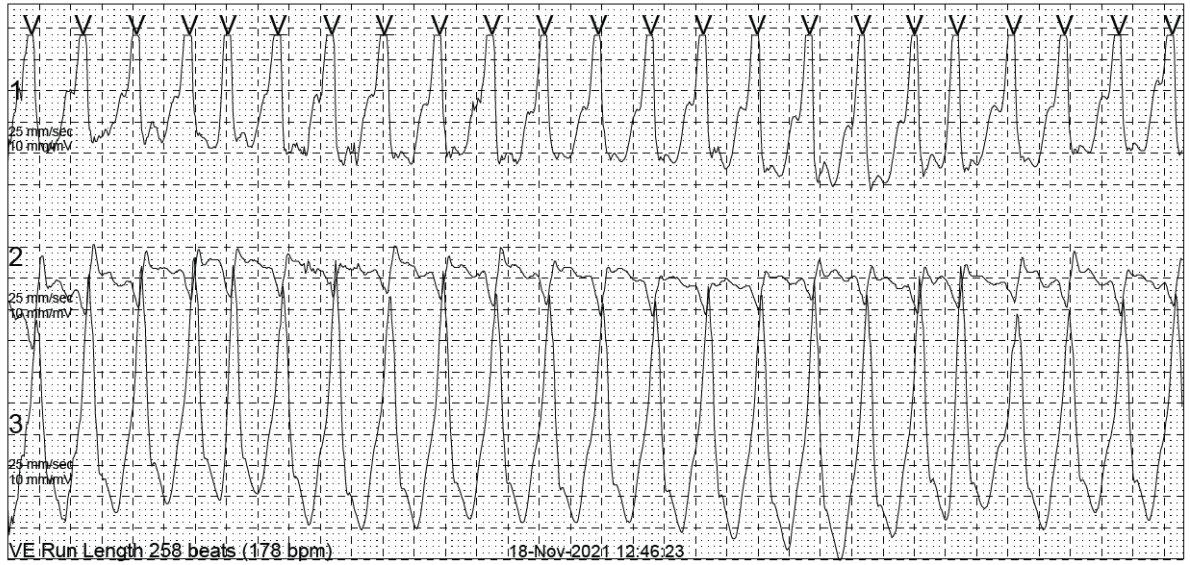
49	Minimum at 01:31:23 19-Nov
92	Average
106	Maximum at 05:07:35 19-Nov
1465	Beats in tachycardia (>=100 bpm), 1% total
351	Beats in bradycardia (<=60 bpm), < 1% total
1.7	Seconds Max R-R at 01:34:01 19-Nov

Supraventriculars (S, J, A)

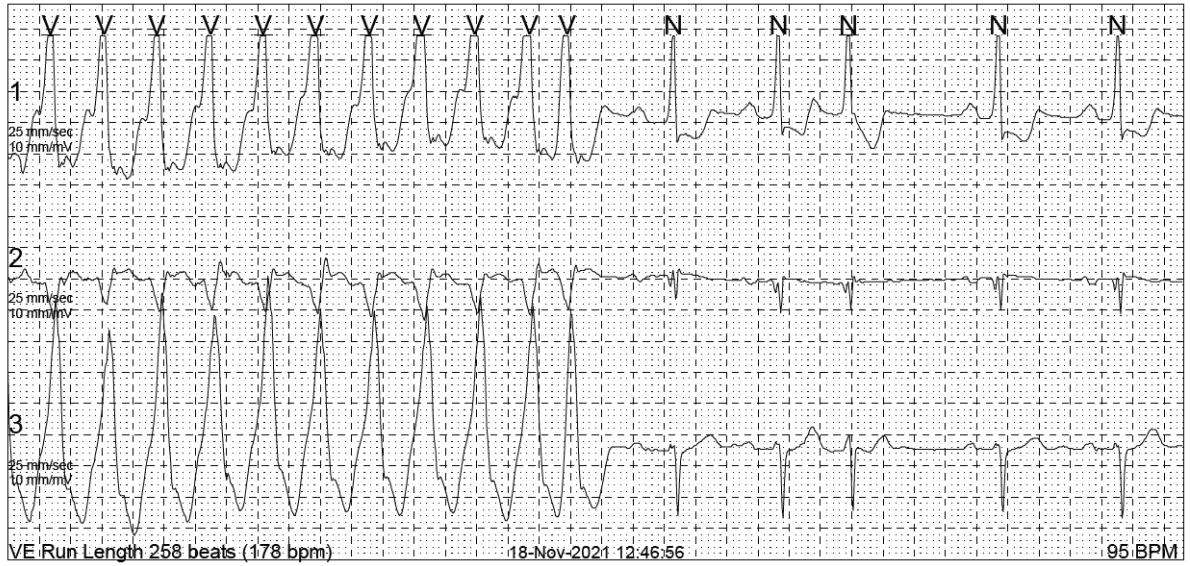
0	Isolated
0	Couplets
0	Bigeminal cycles
0	Runs totaling 0 beats

Min Heart Rate

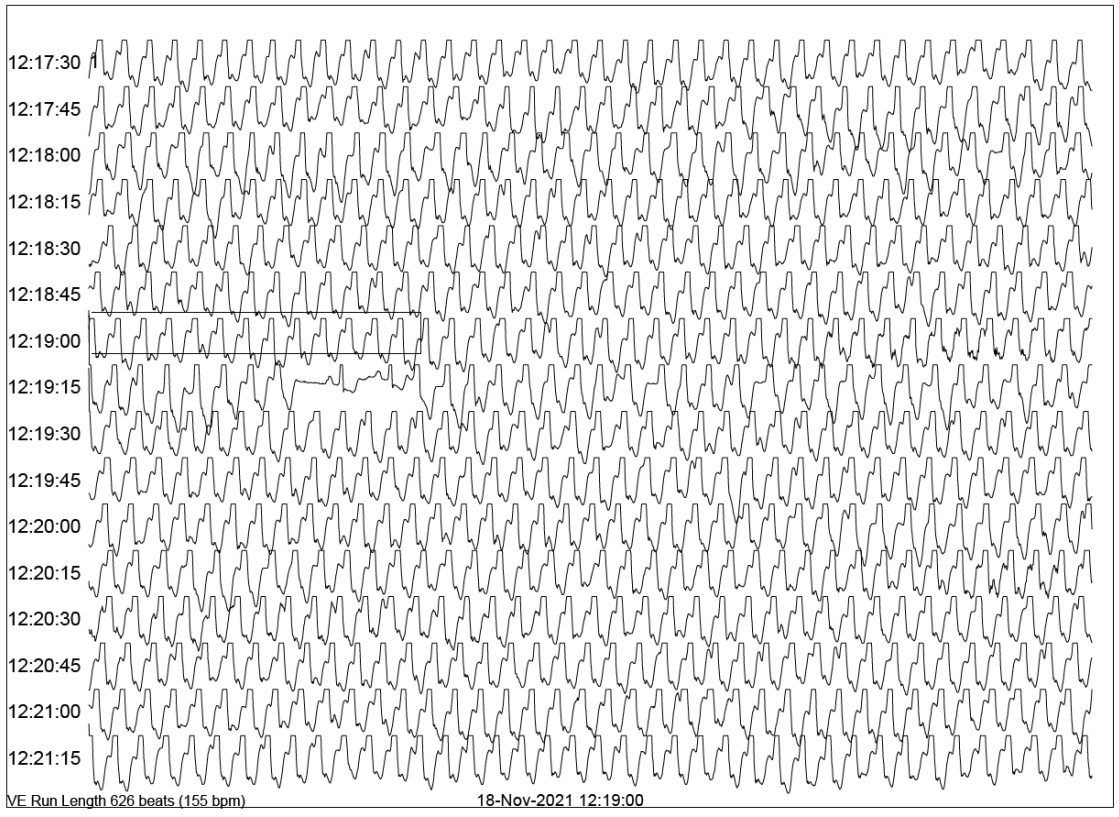


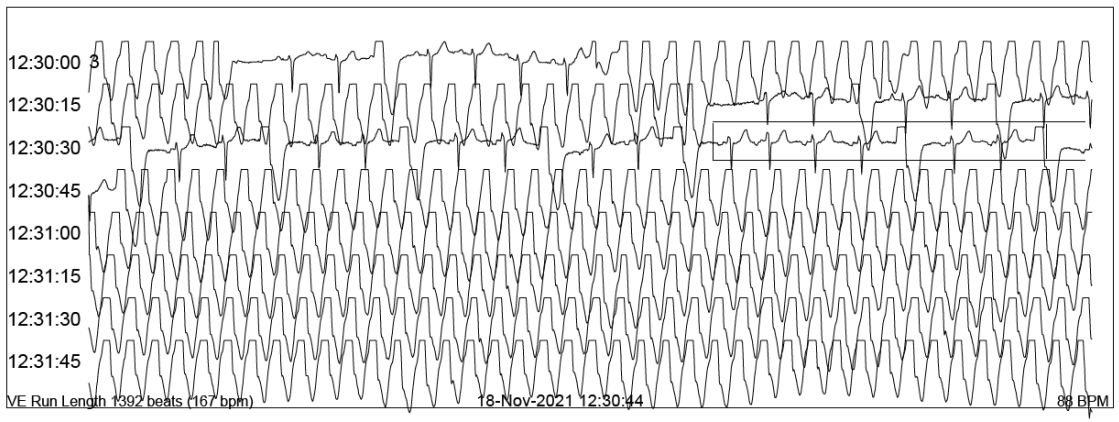


Sustained ventricular tachycardia



답답,어지러움


12:17:30
12:17:45
12:18:00
12:18:15
12:18:30
12:18:45
12:19:00
12:19:15
12:19:30
12:19:45
12:20:00
12:20:15
12:20:30
12:20:45
12:21:00
12:21:15
VE Run Length 626 beats (155 bpm)
18-Nov-2021 12:19:00


12:30:00
12:30:15
12:30:30
12:30:45
12:31:00
12:31:15
12:31:30
12:31:45
VE Run Length 1392 beats (167 bpm)
18-Nov-2021 12:30:44
88 BPM

Case 3

- F/34 with intermittent chest discomfort

General

94883	QRS complexes
0	Paced beats (< 1%)
88	Ventricular beats (< 1%)
11	Supraventricular beats (< 1%)
0	BB beats (< 1%)
0	Junctional beats (< 1%)
0	Aberrant beats
0	% of total time in AF/AFL
10	% of total time classified as noise

Ventriculars (V, F, E, I)

88	Isolated
0	Couplets
0	Bigeminal cycles
0	Runs totaling 0 beats

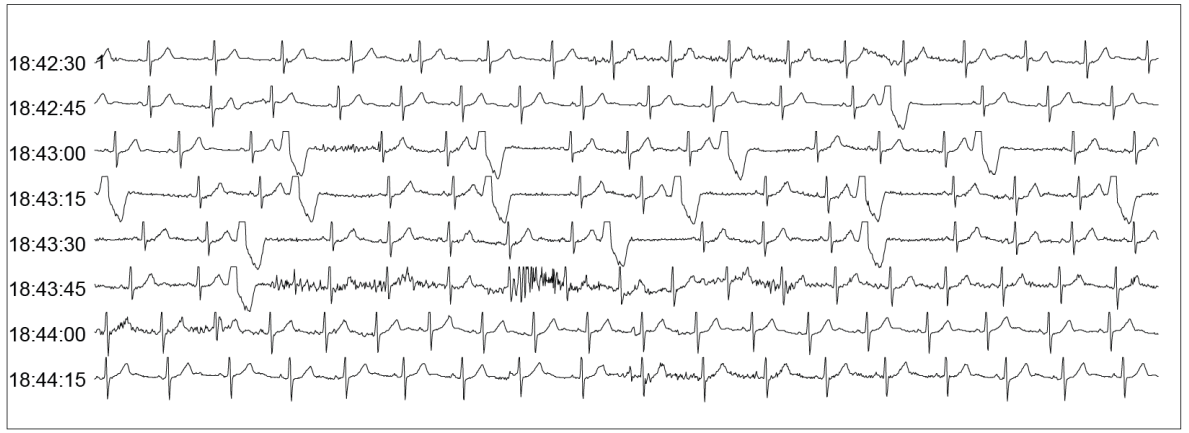
Heart Rates

47	Minimum at 07:45:57 23-Nov
74	Average
130	Maximum at 14:12:03 22-Nov
7629	Beats in tachycardia (>=100 bpm), 8% total
8106	Beats in bradycardia (<=60 bpm), 9% total
1.39	Seconds Max R-R at 18:47:20 22-Nov

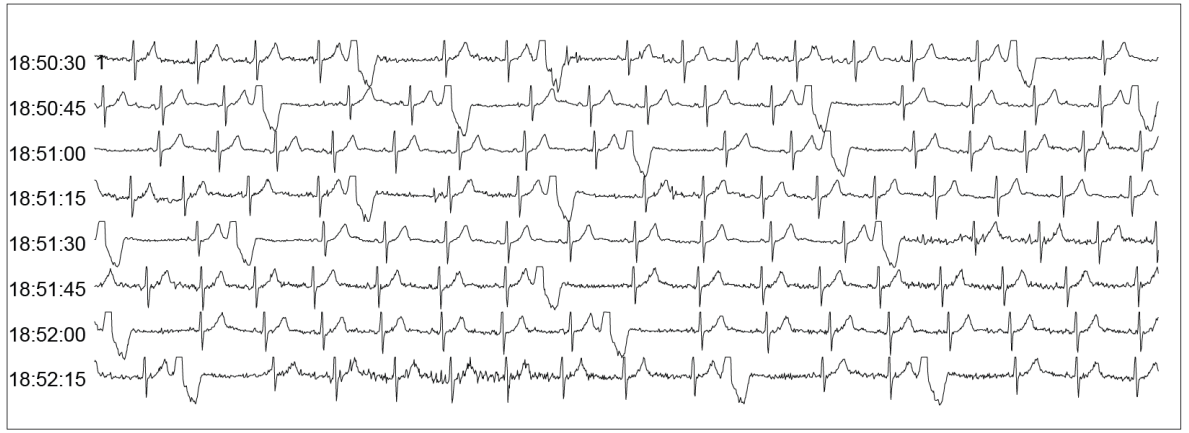
Supraventriculars (S, J, A)

9	Isolated
1	Couplets
0	Bigeminal cycles
0	Runs totaling 0 beats

꿀렁거림



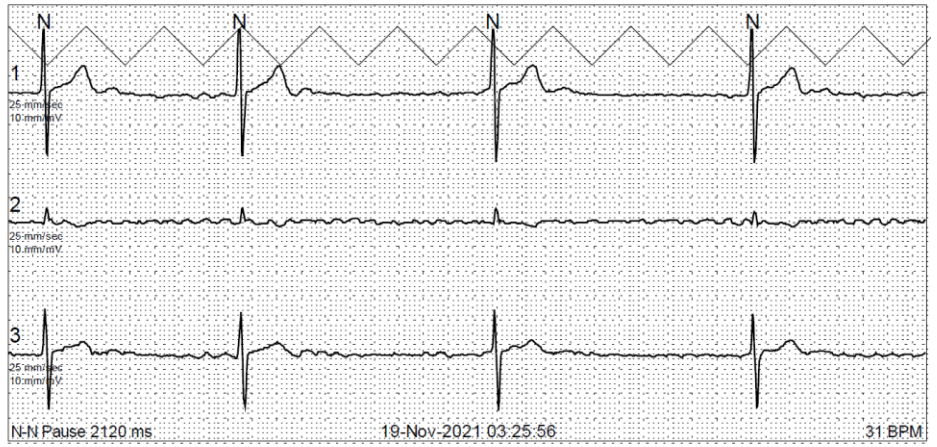
꿀렁거림



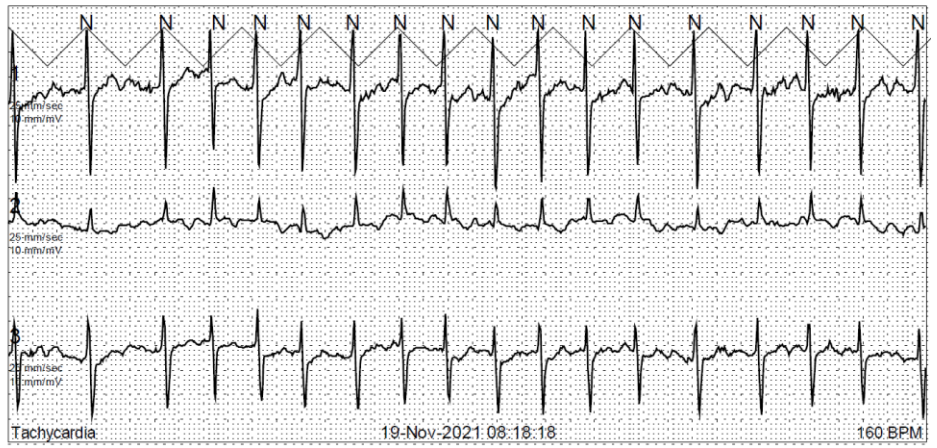
Symptomatic PVC

Case 4

Min Heart Rate



Max Heart Rate



Atrial fibrillation SVR ~ RVR

Case 5.

General

88227	QRS complexes
0	Paced beats (< 1%)
769	Ventricular beats (< 1%)
178	Supraventricular beats (< 1%)
0	BB beats (< 1%)
0	Junctional beats (< 1%)
0	Aberrant beats
0	% of total time in AF/AFL
11	% of total time classified as noise

Ventriculars (V, F, E, I)

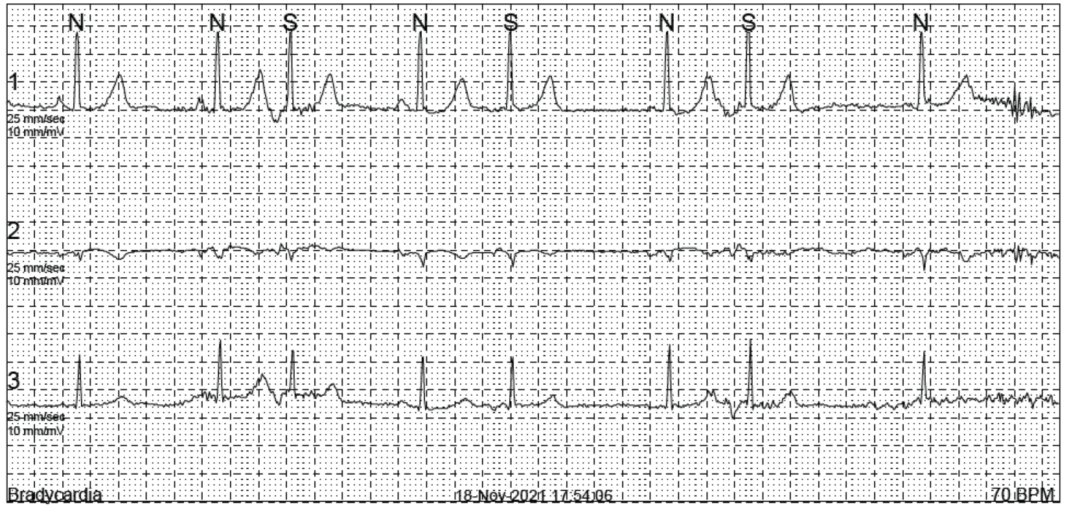
769	Isolated
0	Couplets
0	Bigeminal cycles
0	Runs totaling 0 beats

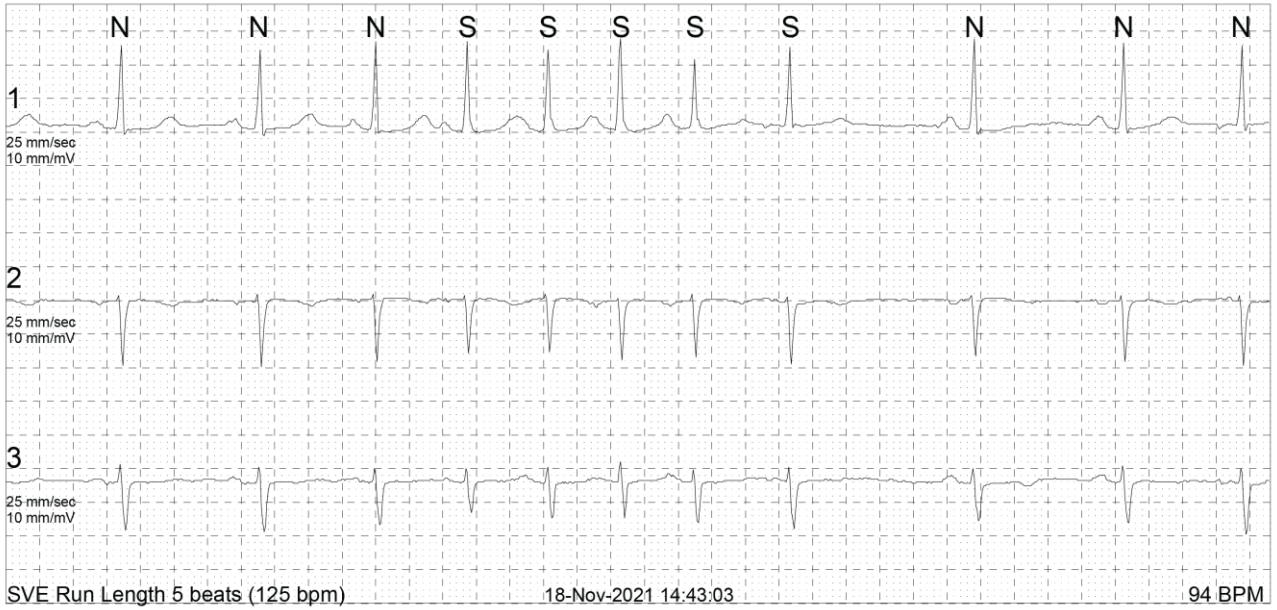
Heart Rates

53	Minimum at 08:40:39 19-Nov
69	Average
105	Maximum at 18:59:11 18-Nov
28	Beats in tachycardia (>=100 bpm), < 1% total
9486	Beats in bradycardia (<=60 bpm), 11% total
1.49	Seconds Max R-R at 00:12:29 19-Nov

Supraventriculars (S, J, A)

120	Isolated
16	Couplets
0	Bigeminal cycles
6	Runs totaling 26 beats
7	Beats longest run 115 bpm 06:43:17 19-Nov
5	Beats fastest run 125 bpm 14:43:03 18-Nov





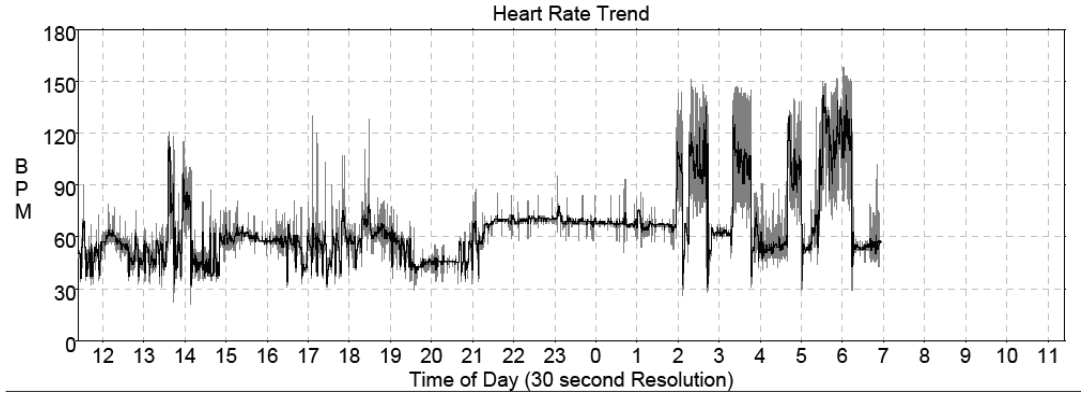
PACs, Short PAT

Case 6.

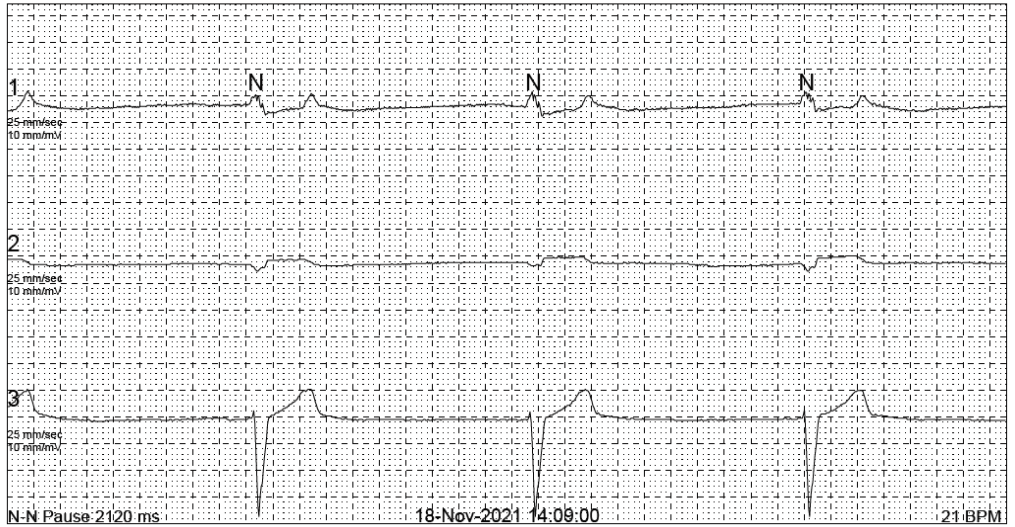
Hourly Summary

*RR Pause Criteria: 2000

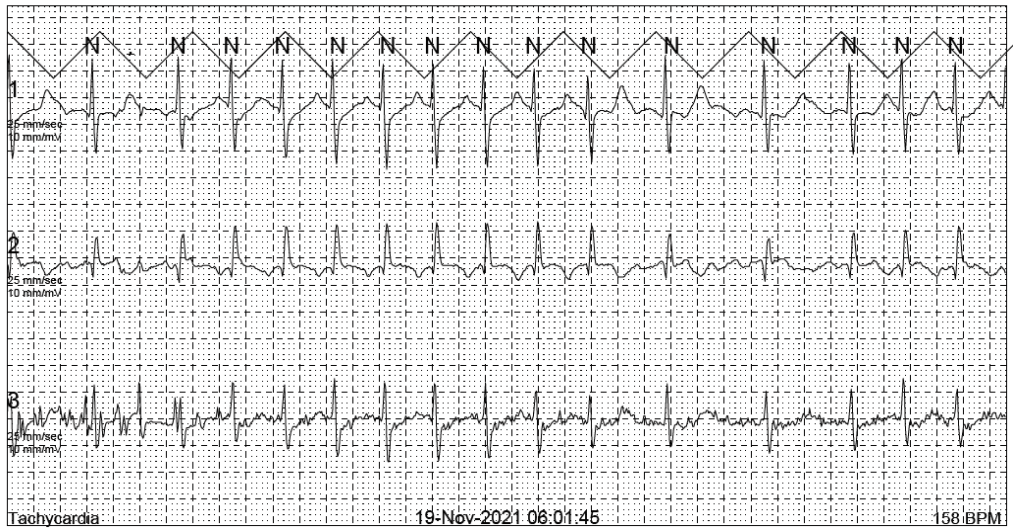
		Heart Rate					Ventricular					Supraventricular				
Hour	Min.s Used	#QRS's	Min.	Ave.	Max.	Pauses	Iso	Cplt	Runs	Max Run	Max Rate	Iso	Cplt	Runs	Max Run	Max Rate
11	36	1770	32	49	90	18	9	0	0	0	0	66	10	0	0	0
12	60	3242	33	54	79	10	20	1	0	0	0	335	8	1	4	78
13	60	3466	22	58	121	15	14	0	0	0	0	141	22	7	4	85
14	60	3099	21	52	101	13	34	0	0	0	0	132	17	3	4	104
15	60	3608	48	60	81	1	1	0	0	0	0	181	10	1	3	96
16	60	3262	31	54	81	16	2	0	0	0	0	224	33	3	4	102
17	60	3216	31	54	130	20	6	0	0	0	0	197	26	6	4	135
18	59	3691	41	62	128	10	1	0	0	0	0	435	23	11	4	133
19	60	2942	29	49	78	27	14	0	0	0	0	104	8	4	3	120
20	60	2817	33	47	69	27	15	0	0	0	0	52	4	1	3	64
21	60	3960	34	66	88	0	1	0	0	0	0	114	19	4	4	120
22	60	4202	58	70	84	0	0	0	0	0	0	5	1	0	0	0
23	60	4166	58	70	95	0	11	0	0	0	0	9	2	0	0	0
00	60	4081	51	68	93	0	0	0	0	0	0	6	6	2	3	180
01	60	4086	53	68	133	0	5	0	0	0	0	203	8	0	0	0
02	60	5019	26	84	151	22	13	0	0	0	0	28	2	0	0	0
03	60	4855	31	81	147	5	13	1	0	0	0	36	15	2	3	106
04	60	4215	41	70	140	2	25	0	0	0	0	170	28	9	4	125
05	60	5471	29	91	152	8	26	2	0	0	0	61	14	5	4	100
06	55	3893	29	71	158	5	24	2	0	0	0	257	38	4	4	112
07	0	0	---	---	---	0	0	0	0	0	0	0	0	0	0	0
	1169	75061	21	64	158	199	234	6	0	0	0	2756	294	63	4	180

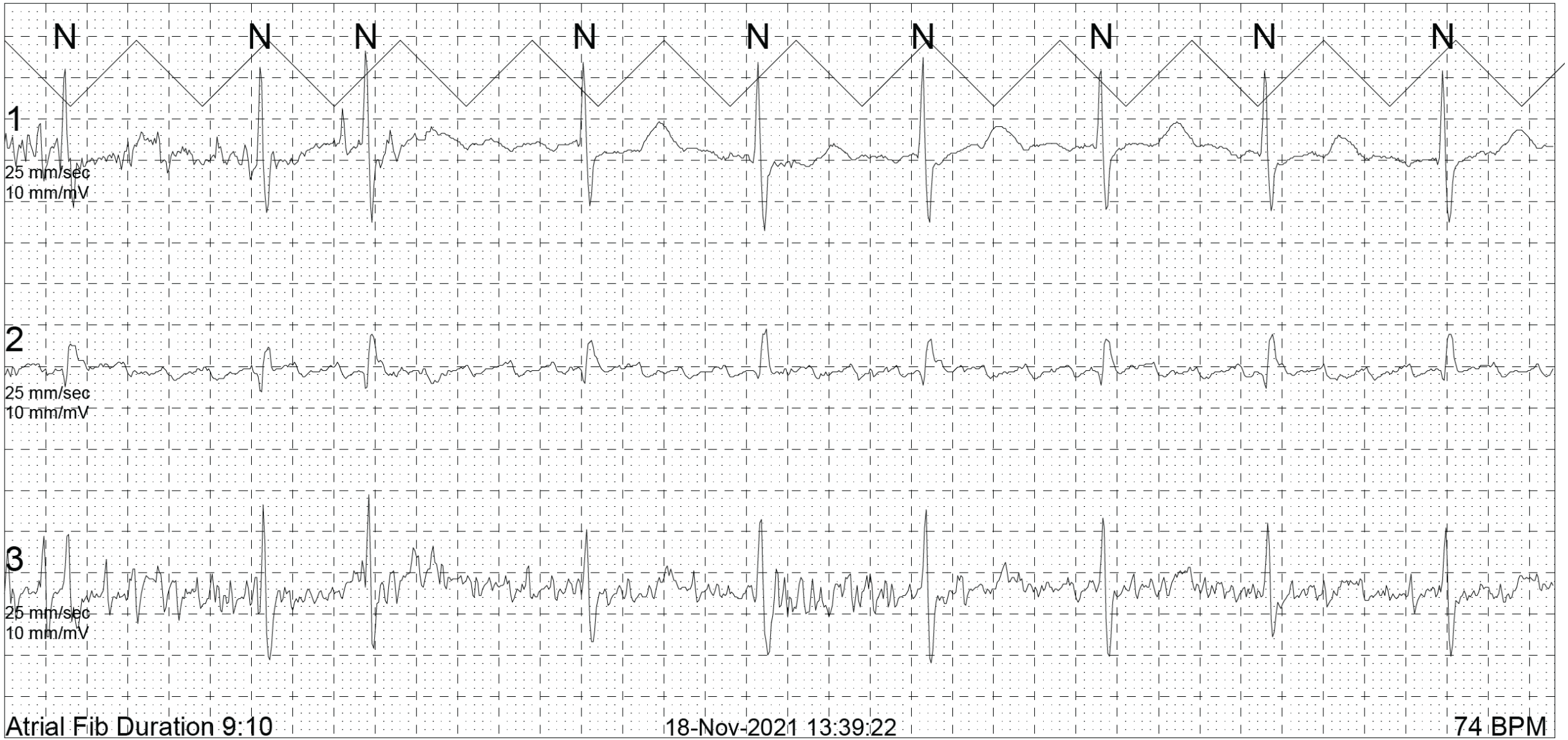


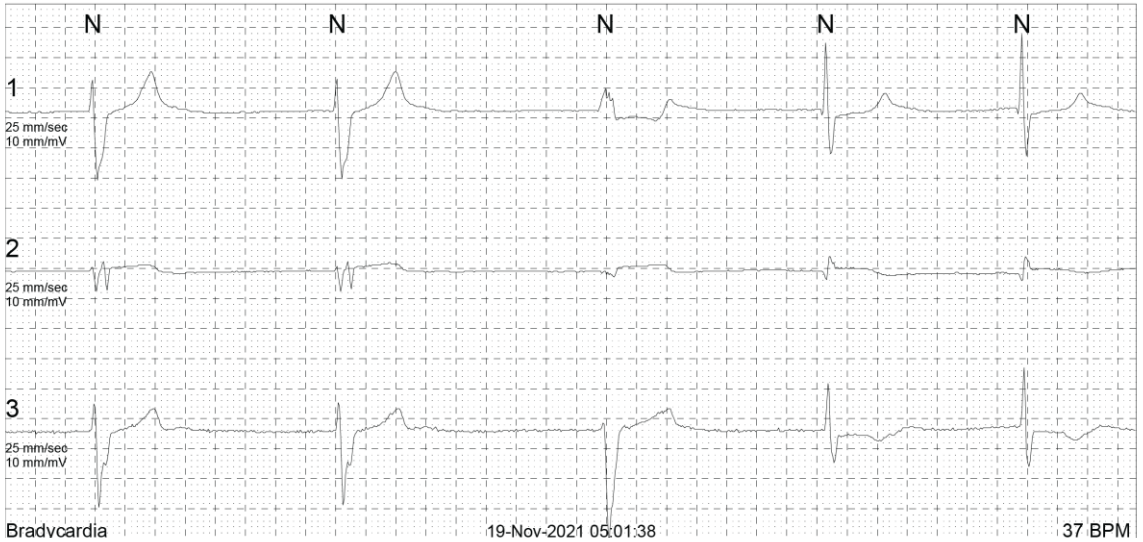
Min Heart Rate

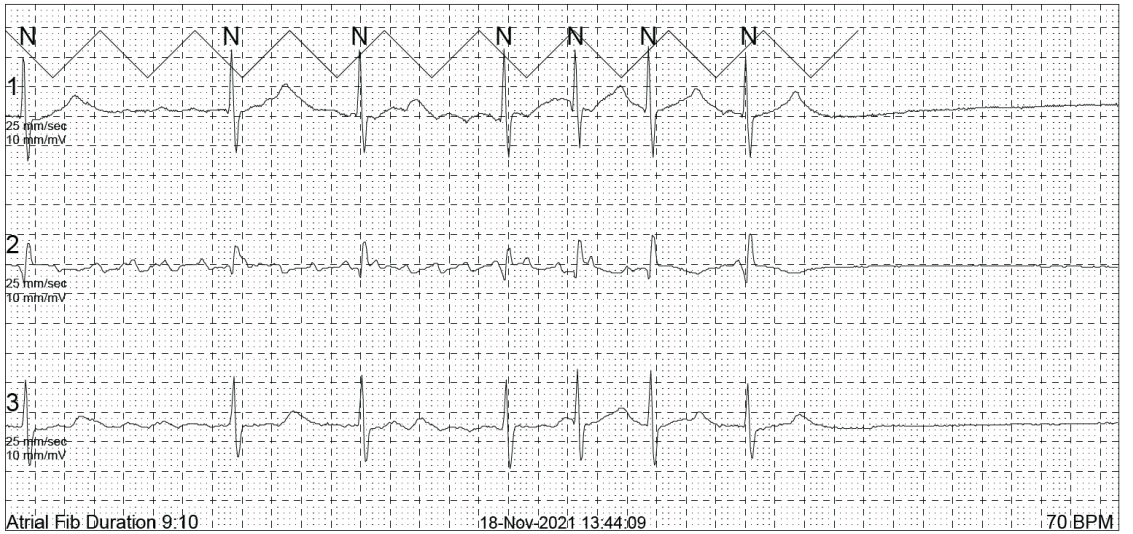


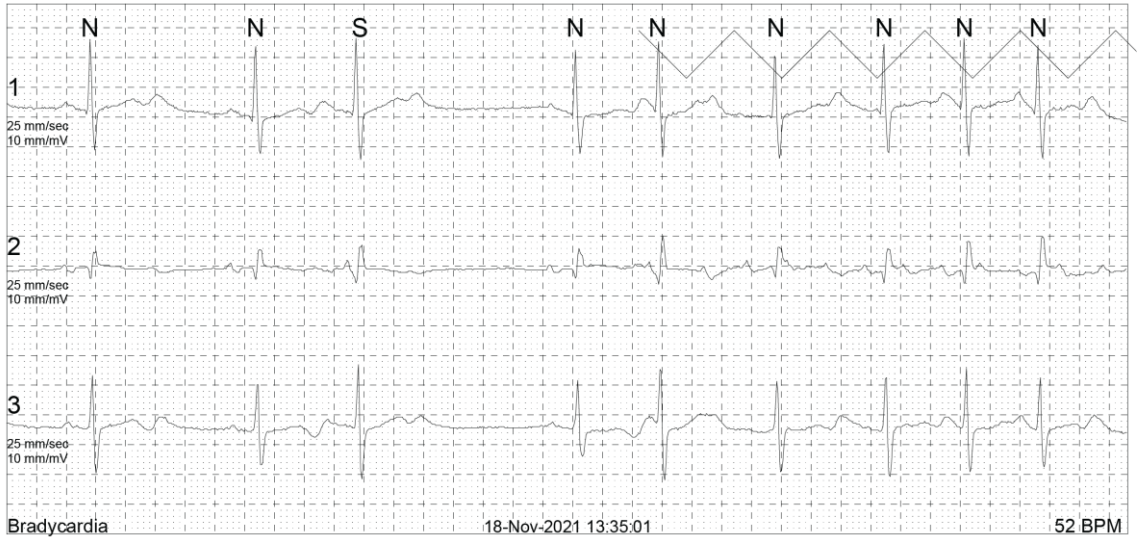
Max Heart Rate

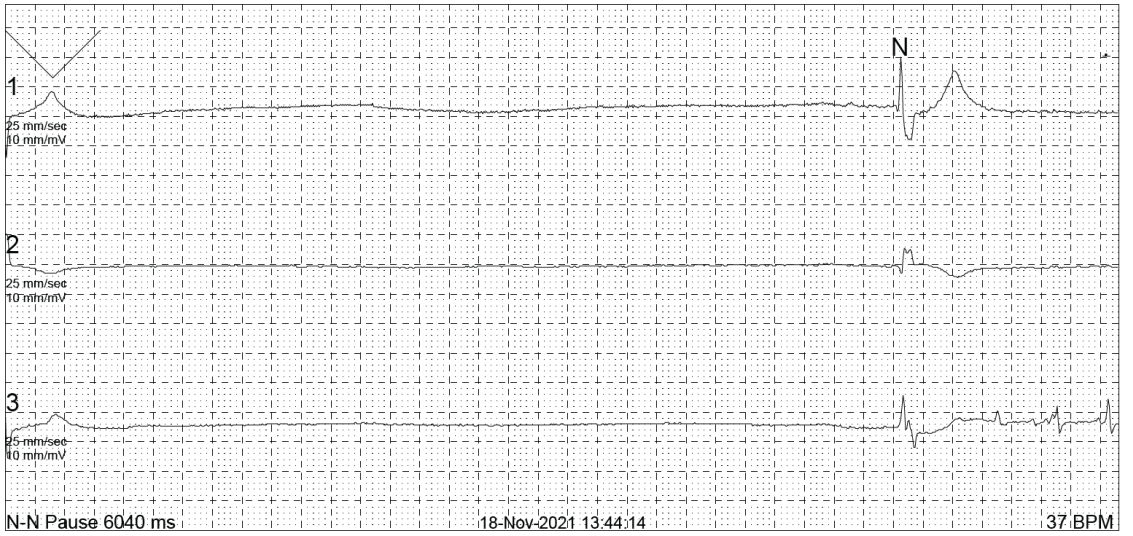



N N N N N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Atrial Fib Duration 9:10
18-Nov-2021 13:39:22
74 BPM

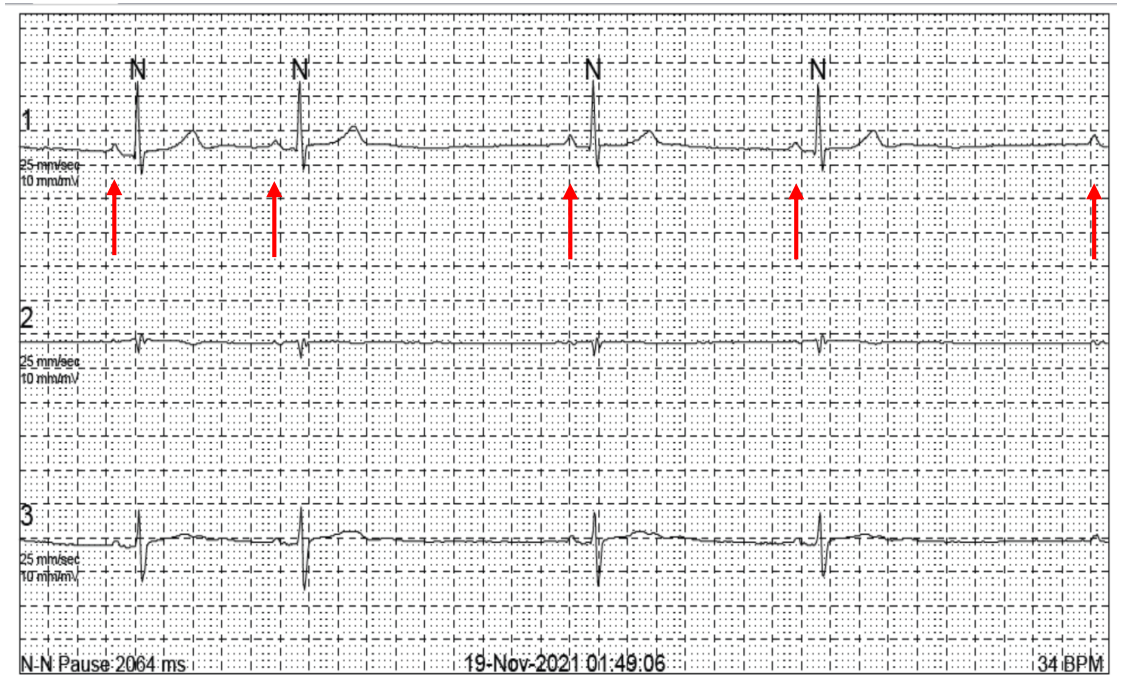

N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Bradycardia
19-Nov-2021 05:01:38
37 BPM


N N N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Atrial Fib Duration 9:10
18-Nov-2021 13:44:09
70 BPM

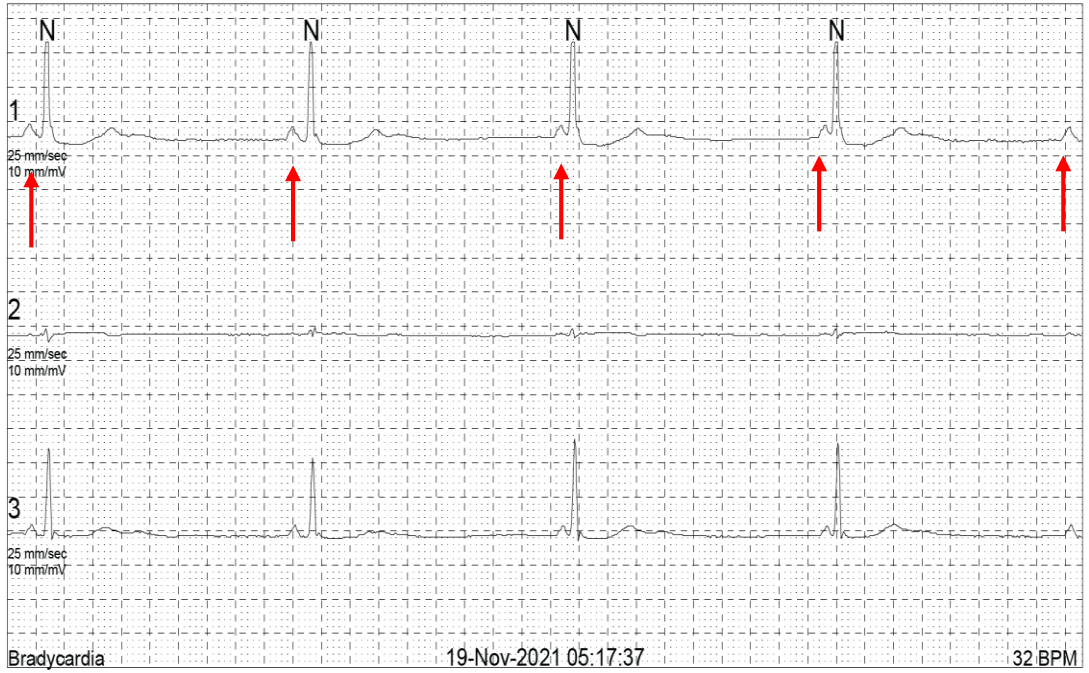

N N S N N N N N N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Bradycardia
18-Nov-2021 13:35:01
52 BPM


N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
N-N Pause 6040 ms
18-Nov-2021 13:44:14
37 BPM

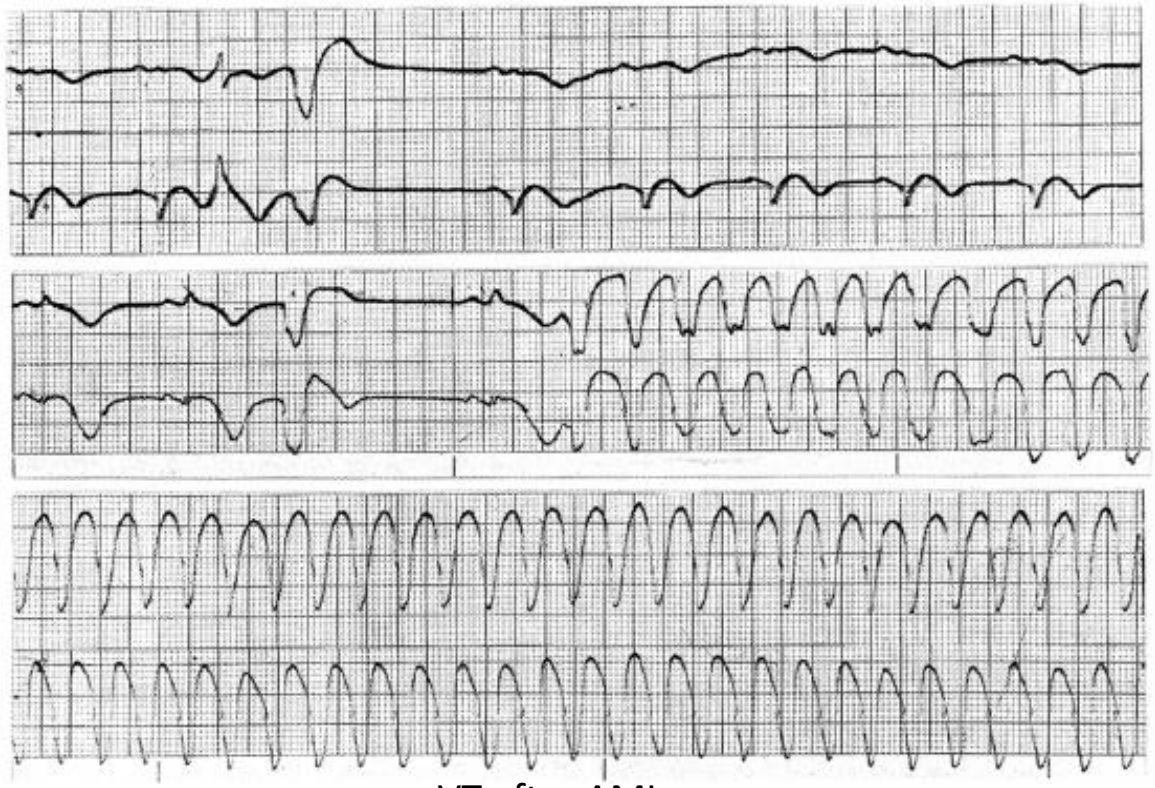
Case 7


N
N
N
N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
N-N Pause 2064 ms
19-Nov-2021 01:49:06
34 BPM

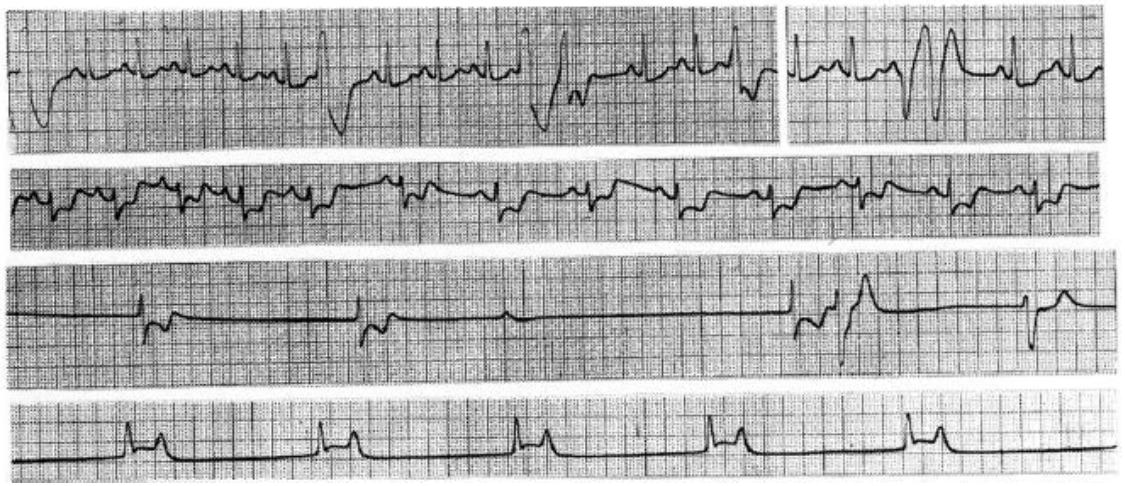
Case 8


N
N
N
N
1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
Bradycardia
19-Nov-2021 05:17:37
32 BPM

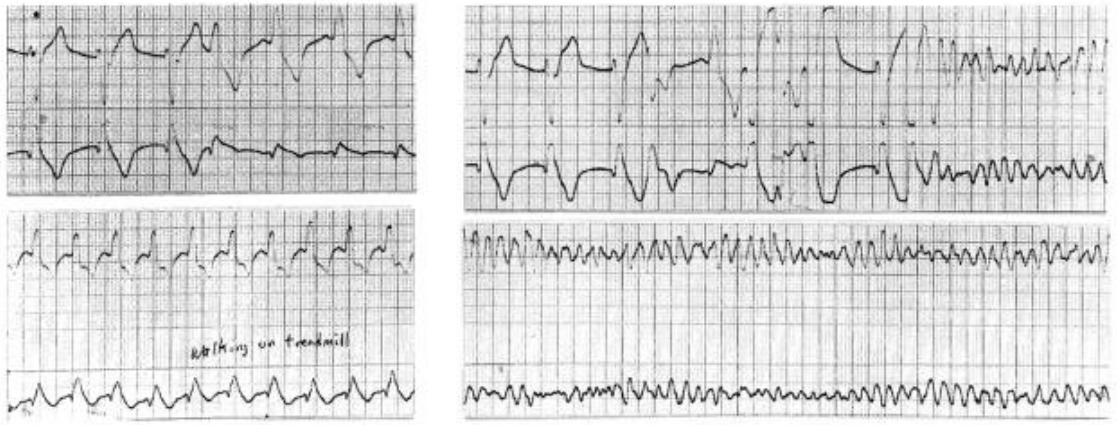
Cases. Sudden Death Recorded During Holter Monitoring



VT after AMI

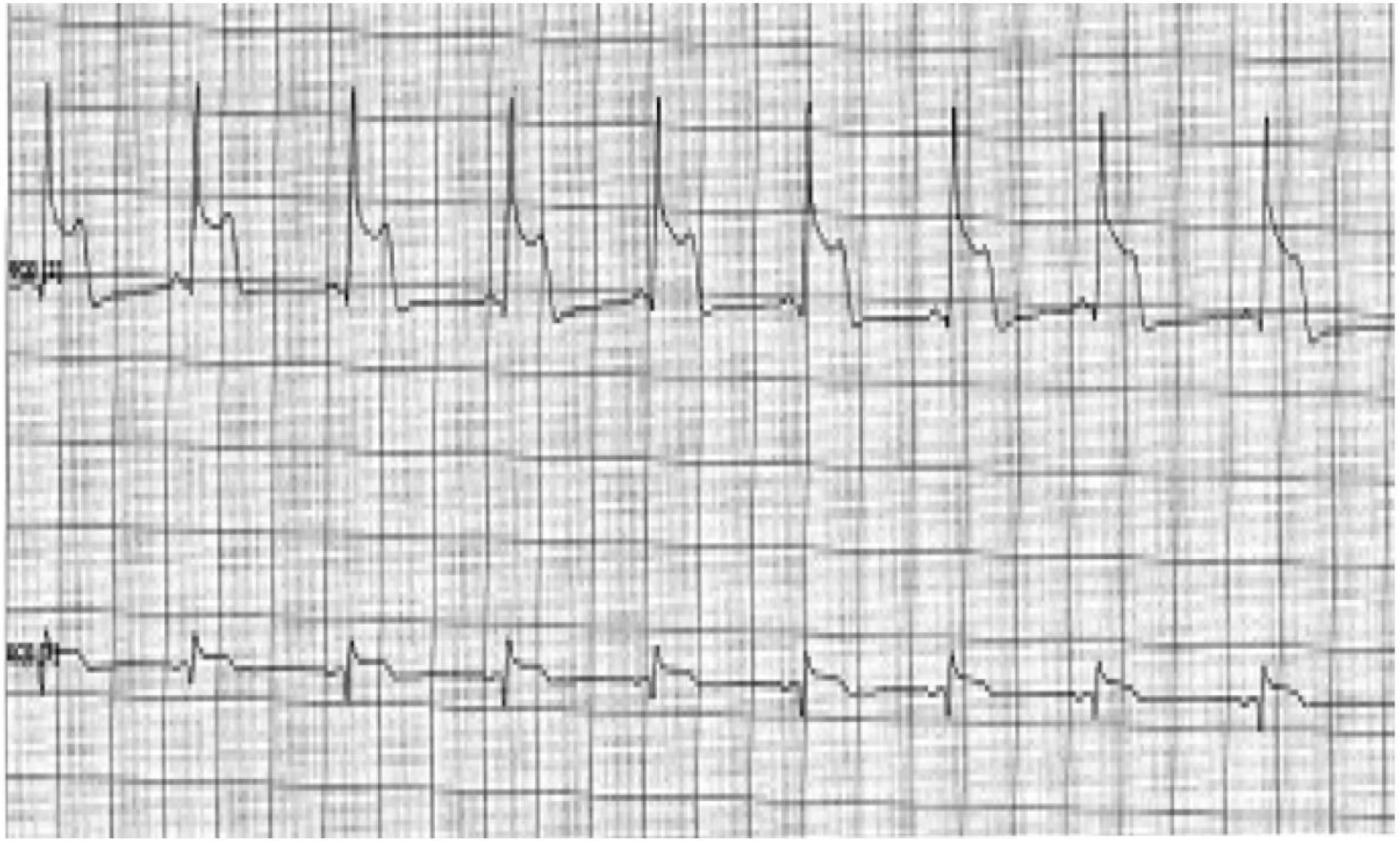


Major bleeding → ST depression → SSS with junctional escape rhythm



Exercise on treadmill → PVCs → VF d/t R on T

Case. Variant angina diagnosed by Holter monitoring who survived SCD



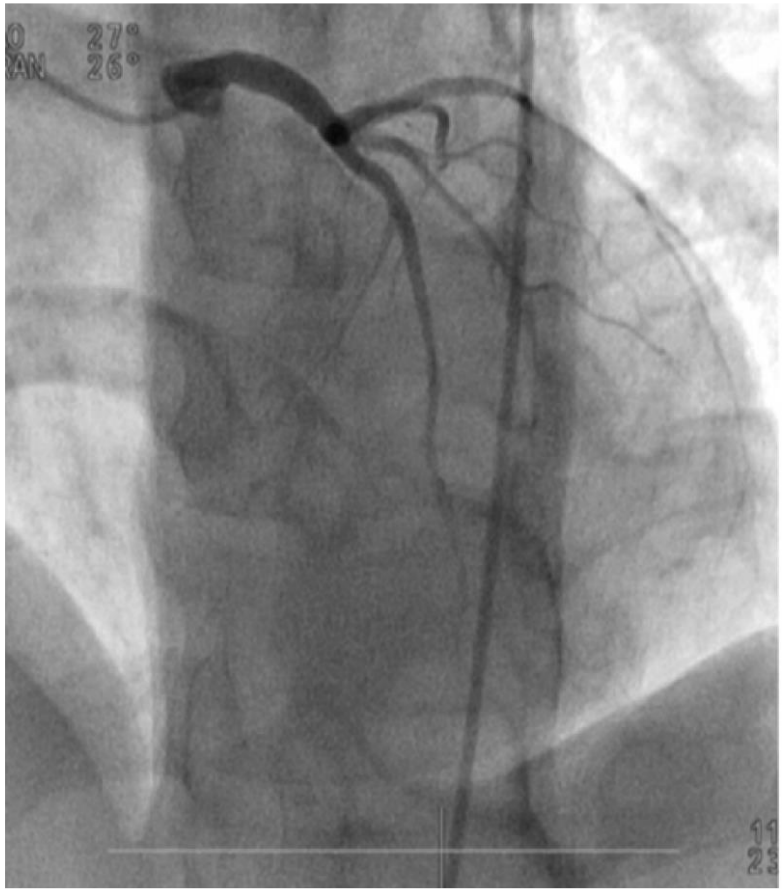


Fig. 3. Holter monitor showing ST-segment elevation.

Case. Syncope during pacemaker

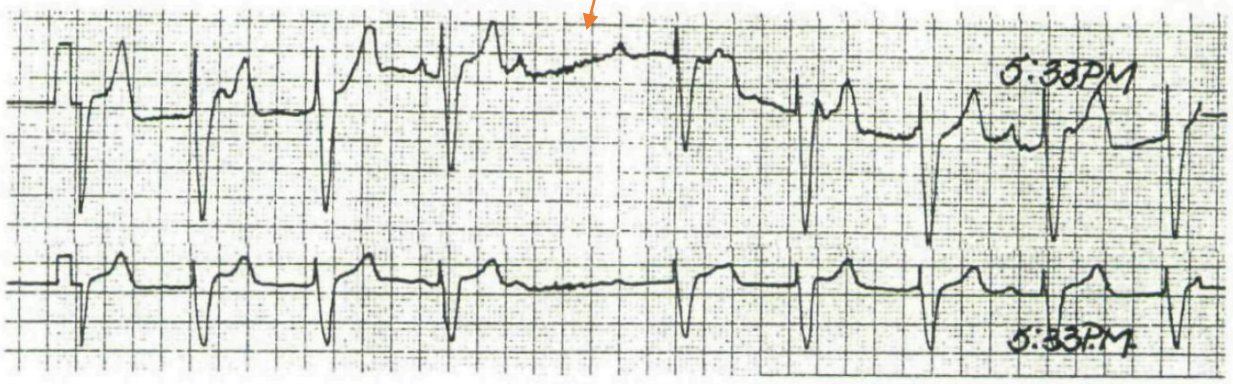
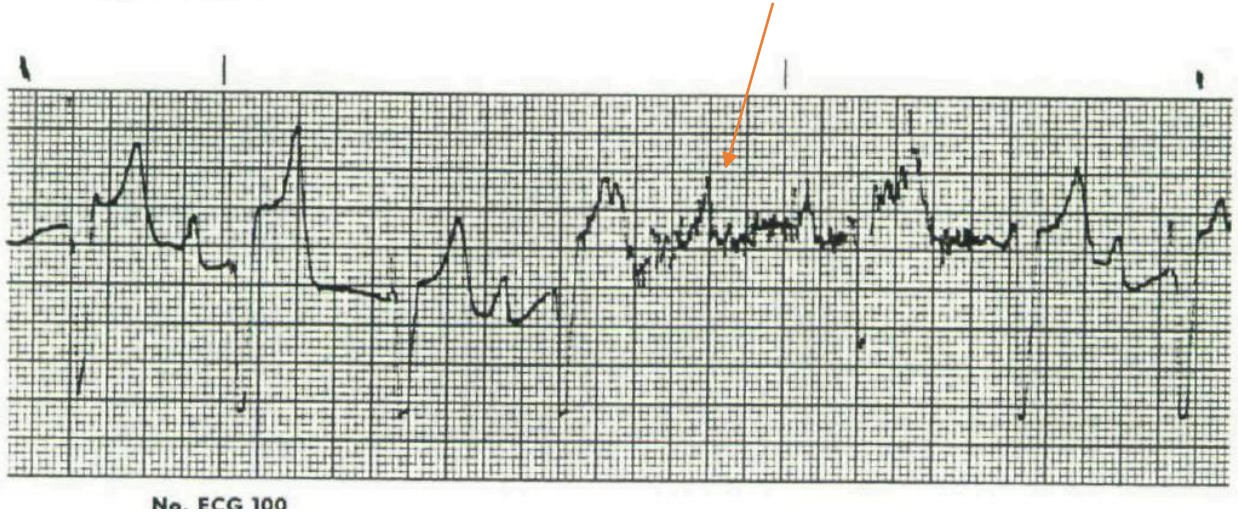


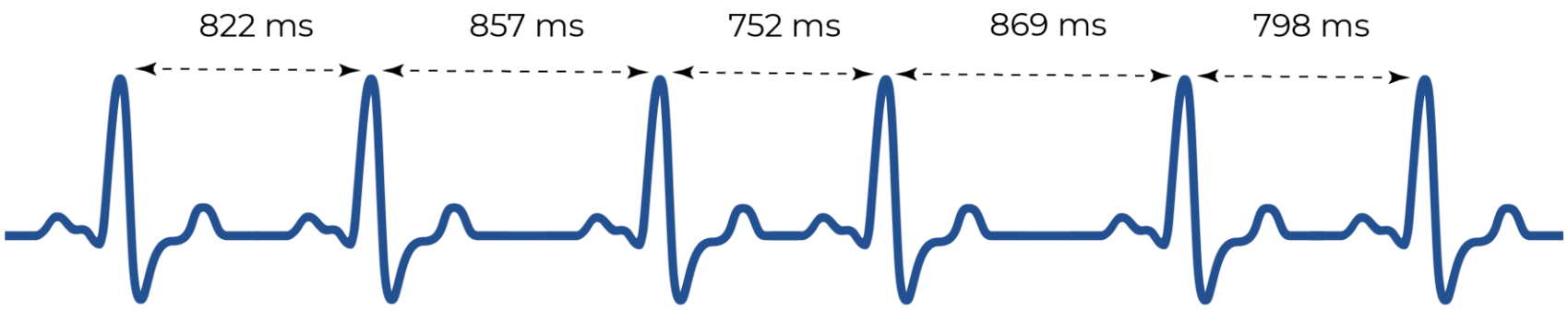
Figure 1. *Two-lead Holter monitor of patient 1 After four paced beats, asystole associated with a baseline "artifact" is observed This was found to represent myopotential inhibition of the pacemaker*



Heart rate variability

- **Heart rate Variability**: measure of variance in time intervals between successive heartbeats
- **Abnormal heart rhythm variability**: autonomous imbalance and associated with worse cardiovascular outcome
- Strong and independent predictor of mortality after an acute myocardial infarction

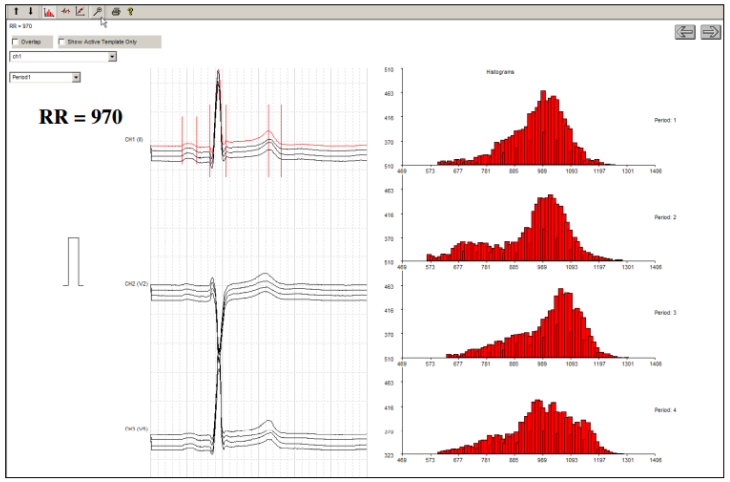
HRV = variation between beat to beat intervals

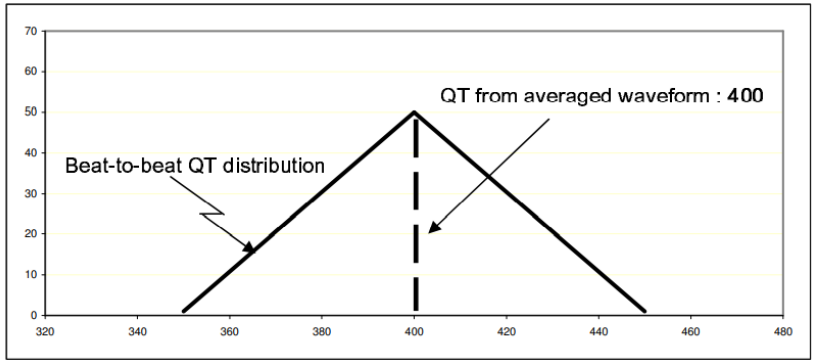


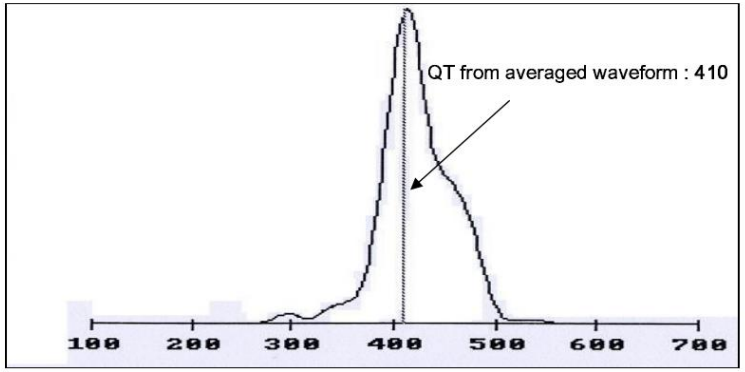
Heart Rate = beats per minute (on average)

QT prolongation

- QT interval:
- Causes: certain genetic conditions, hormonal imbalances, incorrect concentrations of minerals in the blood, Certain medications
- Considered an important marker for the risk of life-threatening arrhythmias

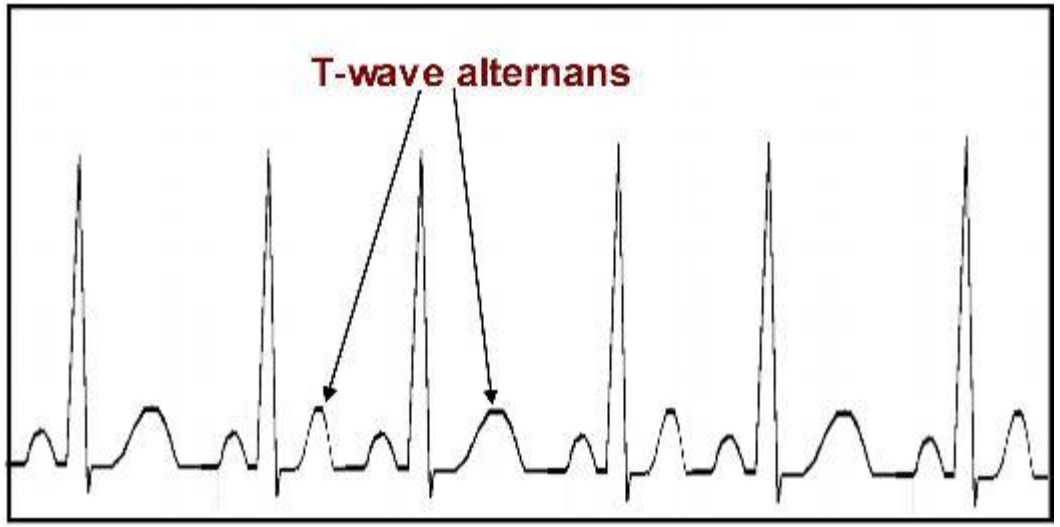






T wave alternans

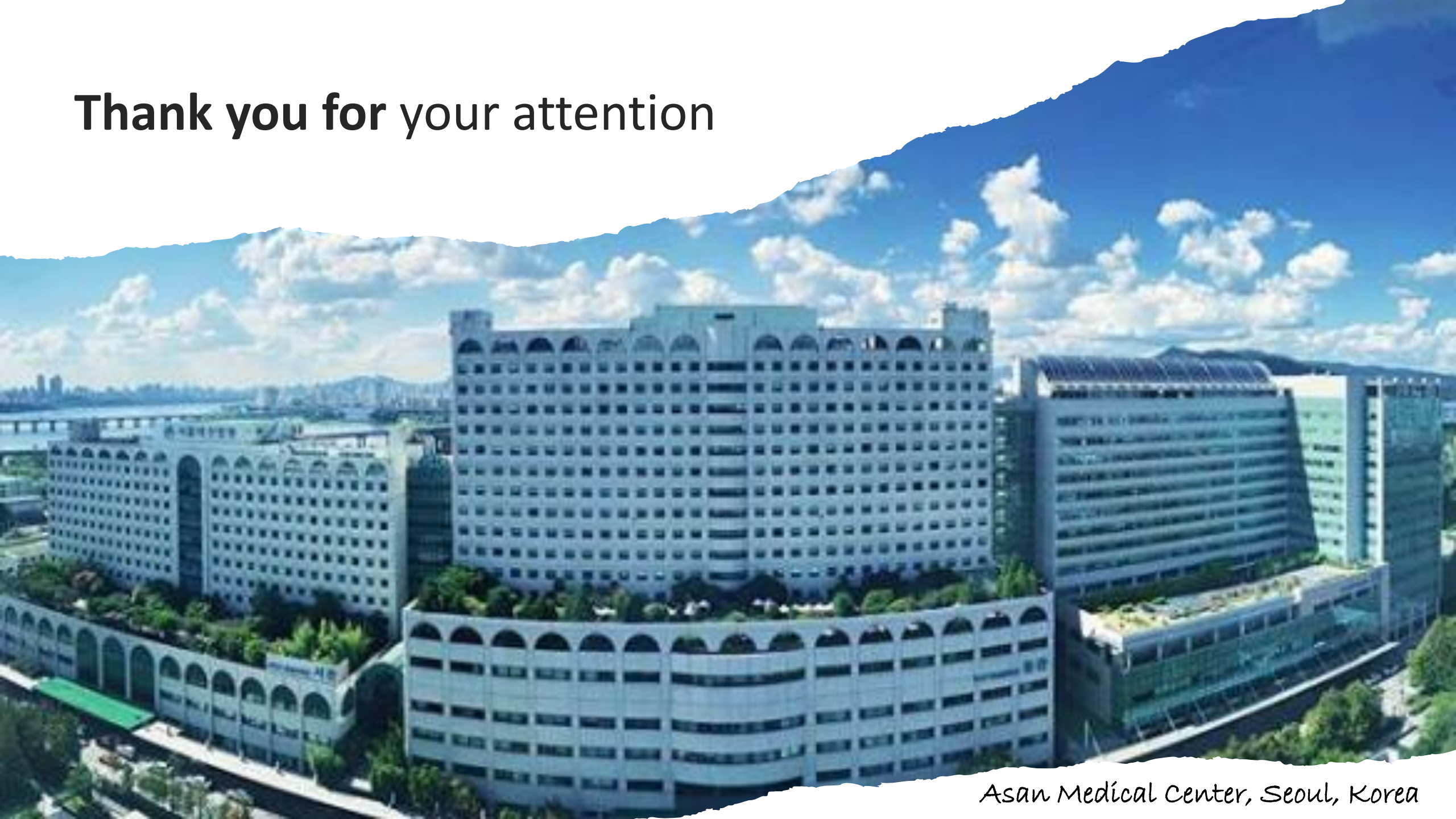
- T-wave alternans (TWA): a consistent beat-to-beat alternation in the morphology of the ST segment and/or the T wave, reflecting temporal and spatial heterogeneity of repolarization
- Considered as an index of susceptibility of sudden cardiac death



Summary

	Holter monitoring	Implantable loop recorders
Advantages	Low cost; continuous monitoring	Duration of monitoring up to 3 years - No need for patient collaboration - Remote monitoring possible
Limits	Short duration of monitoring (generally 24–48 hours; no more than 2 weeks) - Compliant patients	High cost - Minimally invasive surgery for implantation - Non-continuous monitoring - ECG storage limits
Indications	Initial evaluation of patients with syncope, palpitations, dizziness and frequently recurring symptoms (≤1 week) cryptogenic stroke Rate control therapy in AF patients	Infrequent syncope or palpitations in patients with suspected arrhythmias and >1 month inter-symptom intervals - Patients with cryptogenic stroke and high suspicion of AF despite negative evaluation with 2-week Holter monitoring

Thank you for your attention



Asan Medical Center, Seoul, Korea