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THE CLINICAL IMPORTANCE OF MYOCARDIAL IMPEDANCE IN PACEMAKER IMPLANTATION

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Foreword

With the advance and development in electric circuitery, togeter with improvements of the battery which has resulted in the decrease of current consumption with in the pacemaker, combined with the decrease in the rate of breakdown in the electric circuit and the battery, the service life of pacemaker has been considerably extended(6).

The present workers conducted a detailed investigation on the following points, a detailed study on the threshold voltage and current at the time of implantation and replacement of pacemaker together with the results of measurements of the myocardial impedance, the changes of load resistance accompanied by the output voltage and current of 2 types of pacemaker (Constant voltage, Constant current), together with the changes in results of battery consumption rate.

Bases on the above the importance of impedance from a clinical point of view were investigated.

Objective

In a total of 150 cases over the past 3 years in which pacemaker implantation and relpacement were conducted we carried out a simultaneous threshold voltage and current measurement and at the same time we made calculations on the myocardial impedance.

Of the 150 cases which required endcardial lead the cases were 138 cases. The breakdown of the 138 cases was 111 initial implantations and 27 replacements. The surface area of the electrode was 12-14 mm^2, one case of initial implantation was 8 mm^2 and in 2 of the replacement cases a lead of 53 mm^2 was used.

The number of cases in which myocardial lead was required were 39 cases, which can be broken down to 8 cases of initial implantation and 31 cases of replacement.

The respective lead resistance was from 6-130 ohm which shows a considerable difference and the surface area of the lead and a comparative investigation was run disregarding the difference in conditions described above.

Therefore we mainly studied the cases in which the endcardial lead was used where the shape of tip of the lead, the surface area and the resistance were more or less alike of these cases we mainly studied the cases in which initial implantation were made.

In addition measurements were made on the changes in output(voltage, current) accompanying the load resistance of pacemaker implantation together with the extent of battery consumption.

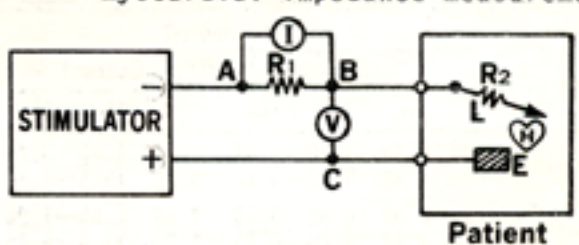
The acute phase referred to here is the period which accompanies the initial implantation and the chronic phase refers the period 3 months after the initial implantation.

Method

1) Measurement of threshold and myocardial impedance

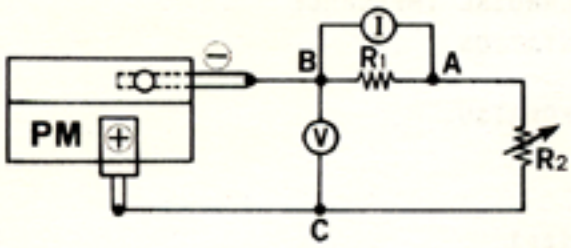
As shown in Fig.1, as the stimulater, threshold analyzer 365B produced by Siemens-Elema Co. and used in 128 cases, together with E2991 Portable Pacemaker produced by Device Company applied in 22 cases were used(1). Current values were measured between AB and voltage values were measured between BC. Myocardial impedance were calculated at the stimulating voltage and current value using Ohm's law.

Fig.1 Diagram of threshold and myocardial impedance measurement



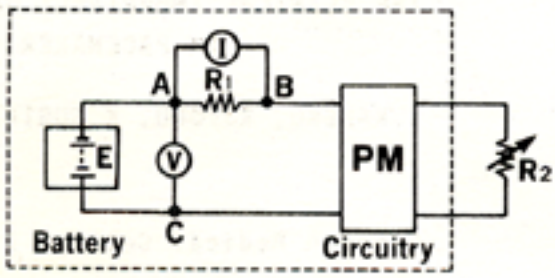
R1 ; 100 Ω.
R2 ; Resistance of Lead.
E ; Indifferent electrode.
L ; Lead.

Fig.2 Diagram of pacemaker output measurement



PM ; Implantable pacemaker.
R_1 ; 100Ω.
R_2 ; 1000Ω.
* Pacer at Room temperature.

Fig.3 Diagram of pacemaker battery consumption measurement



E ; Battery.
R_1 ; 10Ω.
R_2 ; 1000Ω.
* Pacer at Room temperature.

The impedance from the threshold (voltage, current) values are referred as the "Threshold Impedance" and when the same electric pressure using the implanted pacemaker, was passed through the electrodes the measured impedance was referred to as the "Pacing Impedance".

These stimulating methods used at the time of measurements are values, which are stimulated unipolerly and cathodaly and as the indifferent electrode stainless steel electrode DU301 mamifactured by the Americal Technology Company were used.

2) Changes in pacemaker output at the time of load resistance variation

As shown Fig.2, the load resistance (R_1+R_2) of pacemaker output terminal is varied, and measurements were made on current, and voltage values between AB and BC as the occasion arose.

3) Pacemaker battery consumption change at the time of varying of the load resistance

As shown in Fig.3, the implanted pacemaker was broken down, into electric circuit and power source (battery), and the circuit and the power source were recombined with a 10 ohm resistance. The changes in load resistance accompanying the battery voltage and current variation were measured between BC and between AB, and the battery consumption rate was expressed as the corresponding values of the respective load resistance against a 600 ohm load.

The measurement of voltage and current values in the cases of 1)2)3) were made by Hitachi Model V121 2 channel oscillo scope, and recorded on a Polaroid film and from this the voltage and current values were measured.

Results

1)Threshold

The threshold shows a rise in the chronic phase, and maximal threshold was seen as 13.5 mA in endcardial lead cases and as 22 mA in myocardial cases (measured with 365B)(Fig.4, Table 1,2, 3,4,5).

2) Impedance

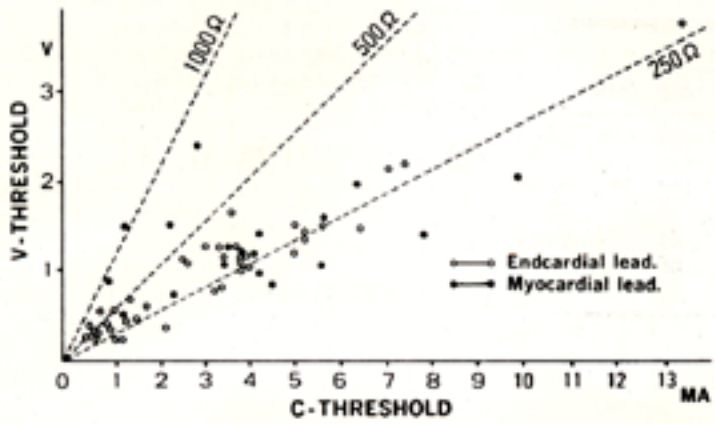
In cases which used 365B "Threshold Impedance" in the group which used endcardial lead shows a broad difference with a maximum of 733 ohm and minimum of 153 ohm, and in the group using myocardial lead, the similar result is seen with a maximum of 500 ohm and minimum of 144 ohm.

Table 1 Threshold and "Threshold Impedance"

Lead	Phase	Threshold						"Threshold" Impedance			No. of Cases
		Voltage			Current						
		m	Max	Min	m	Max	Min	m	Max	Min	
Endcard	accute	0.45	1.70~0.13		1.13	4.60~0.46		416	733~153		72
	chronic	1.48	3.80~0.70		5.02	13.5~2.30		299	449~235		25
Myocard	accute	0.55	0.60~0.50		1.58	1.95~1.20		362	416~308		2
	chronic	1.42	3.80~0.75		5.25	22.0~5.25		303	500~144		26

* Measured with 365B, 1msec pulse.
* Measured at Leading edge.

Fig.4 Threshold and "Threshold Impedance"



* Measured with 365B.
* Measured at Leading edge.

An important point in the measurements of impedance is that the resistance of the myocardium contains a reactance component. Because of this, the resistance value in the case of pulse stimulating, and in the case of pulse leading edge is different from the case of resistance of the trailing edge.

In addition, in the case of resistance value of the trailing edge, there is a considerable difference betwen the case of "Threshold" and the "Pacing" (Table 2).

The rising rate of the resistance value in the case of the trailing edge as compared with case of the "Threshold" showed a low rate in the "Pacing".

This was the same in the case of average impedance. So the "Pacing Impedance" showed lower values than the "Threshold Impedance". With the increase of pulse width the average impedance rises (Table 3).

The difference between the resistance value in the "Threshold" of the leading edge and the resistance value in the "Pacing", it was shown that "Pacing"/"Threshold"=94.5%.

3) The change in pacemaker output in the presence of changes in load resistance

In a constant voltage pacemaker, the voltage output change accompanying the changes in load resistance is small but the change in current output is large. The current output in the case of a 200 ohm load is, 271% of that of the 600 ohm load (Table 3, Fig.5).

In a constant current pacemaker, the changes in current output accompanying the change in load resistance is small.

If the resistance load is higher than 600 ohm, the current output of the 2 types of pacemakers would both show a decrease, and when the load is 1000 ohm, it was approximately 60-70% of 600 ohm load output.

Table 2 "Threshold Impedance" and "Pacing Impedance"

Pulth width (ms)		"Threshold" Volt	"Threshold" $Imp\bar{m}$	"Threshold" $\frac{Imp\bar{m}}{ImpL}$	"Threshold" $\frac{ImpT}{ImpL}$	"Pacing" Volt	"Pacing" $Imp\bar{m}$	"Pacing" $\frac{Imp\bar{m}}{ImpL}$	"Pacing" $\frac{ImpT}{ImpL}$	$\frac{\text{"Pacing" } Imp\bar{m}}{\text{"Threashold" } Imp\bar{m}} \times 100$
0.5	$\bar{m}$	0.48	576	1.41	1.82	4.25	472	1.23	1.45	82.5 (%)
	Max	0.74	729	1.56	2.12	3.60	569	1.33	1.61	94.6 (%)
	Min	0.30	529	1.28	1.56	4.85	403	1.17	1.30	69.0 (%)
1.0	$\bar{m}$	0.38	757	1.95	2.91	4.85	516	1.35	1.73	74.4 (%)
	Max	0.55	896	2.55	4.10	4.85	612	1.52	2.03	51.4 (%)
	Min	0.27	670	1.65	2.29	3.70	459	1.19	1.52	77.6 (%)

(7 Cases)

* Acute cases with endcardial lead.
* Measured with 365B.
* ImpL ; Impedance at Leading edge.
* ImpT ; Impedance at Trailing edge.
* $Imp\bar{m}$; (ImpL + ImpT)/2

Table 3 Delivered pacemaker output vs. electrode resistance

Output	Pacer model	Load Resistance 200	250	350	600	750	1000	(ohm)
Voltage	DU301	92		100	100	102	102	%
	Prolith	33		60	100		113	%
	Li-2D		42		100		129	%
Current	DU301	271		171	100	82	61	%
	Prolith	105		105	100	88	60	%
	Li-2D		106		100		74	%

* Measured at Leading edge.
* Pacer at Room temperature.
* Load; Pure resistance.

Fig.5 Delivered pacemaker output vs. load resistance

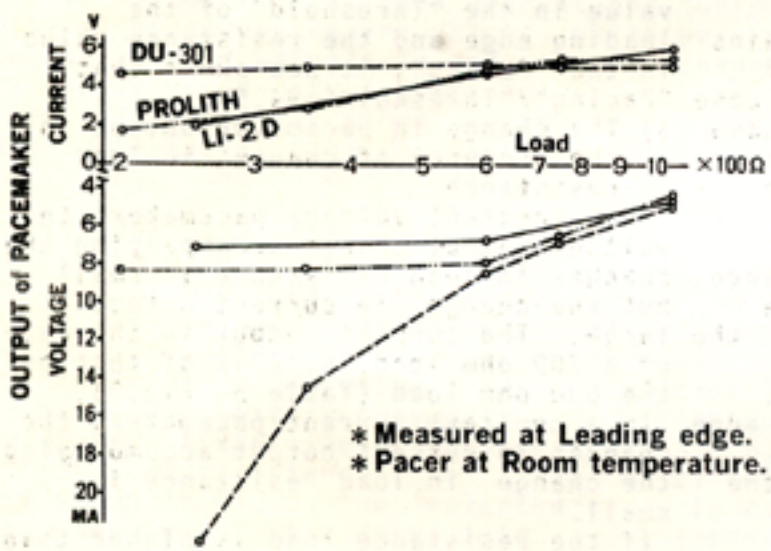


Table 4 Relative battery power consumption at different load

Pacemaker Model	Load Resistance 200	300	400	500	600	700	800	1000	(ohm)
5942	139	120		104	100	91		93	(%)
Li-3D	99		102		100		101	99	(%)

* Measured at Leading edge.
* Pacer at Room temperature.
* Load; Pure resistance.

4) The changes in battery consumption in a pacemaker undergoing load resistance changes

In a constant current type of pacemaker, the changes in battery consumption rate accompanying the changes in load resistance were not seen.

In a constant voltage type of pacemaker, the battery consumption rate showed a large increase with the decrease in load resistance (Table 4). The battery consumption rate at 200 ohm load was approximately 140% of 600 ohm load.

Discussion

1) Threshold and impedance

In a case with a high threshold (voltage threshold 3.8V, current threshold 13.5 mA, impedance 281 ohm) which exceeds the current output of 500 ohm load of the implanted pacemaker, it was possible to obtain satisfactory pacing with an ordinary pacemaker (Fig.4).

This means that evaluation of the threshold should be limited to the relationship of the impedance. Actually in this particular case, the impedance showed a low value of 281 ohm.

Because of the output current of the constant voltage type pacemaker, changes occur with the changes of load resistance, and the output of the pacemaker in this case showed an increase to 18.9 mA.

We must know the impedance to evaluate the suitability of the lead and it is also important to determine the degree of output of the pacemaker.

2) Impedance

Because the resistance of myocardium is an impedance which contains a reactance component, a difference arises between the leading edge impedance and the trailing edge impedance and in addition a difference in impedance arises in the trailing edge, because of the changes in pulse width.

Another important point is the changes in stimulating voltage, the impedance of the trailing edge changes and as a result we cannot use the average impedance of "Threshold" as the average impedance of the "Pacing".

As result of the above, in the caluculation of the output of implanted pacemaker and in order to estimate the service life, the average impedance should not the impedance of the "Threshold" but rather the impedance of "Pacing".

As a general expression of impedance, we should think that the leading edge impedance which shows the least changes under various conditions, should be used.

3) Changes in pacemaker output at changes of load resistance

The importance of impedance when the pacemaker is used is the pacemaker output at the impedance load.

Because of the decrease in the current output at high impedance, in both 2 types of pacemakers, a still lower threshold is needed at pacemaker implantation and replacement.

In contrast, when a constant voltage type of pacemaker is used, bacause in low impedance the pacemaker output increases even in patients with a somewhat high threshold, a complete and dependable pacing can be obtained.

4) Changes in pacemaker battery consumption in the presence of load resistance change

In a constant current type of pacemaker, the battery consumption rate shows no change accompanying load resistance change, whereas in a constant voltage type of pacemaker a considerably large battery consumption increase is seen accompanying the lowering of load resistance. This indicates that in cases in which constant voltage type pacemakers are used, the impedance of the patients have a strong influence on the service life of the pacemaker. This is very important for the management of the patients.

5) Appropriate time of the pacemaker replacement

As an indicator of pacemaker replacement, it has been reported that the decrease in pacemaker rate by battery depletion is one, and in addition the decrease of pacemaker output and also the high patient's threshold require an early replacement of the pacemaker.

It is also known that in the constant voltage type pacemaker when the impedance is low, the service life of the pacemaker is shortened.

Conclusion

1) Pacemakers can be roughly divided into 2 types, constant voltage type and constant current type by the difference in output circuits.

In these pacemakers accompanying the changes in load resistance, the state of affairs in the output and battery consumption differs considerably.

2) The impedance, in clinical cases, shows a wide distribution ranging from 200 to 1000 ohm.

3) Therefore, here after it would necessary for pacemaker output indicating data, to be indicated by both voltage output and current output accompanying the change in load resistance.

In the service life of pacemakers, it would be also necessary to indicate the service life accompanying the changes in load resistance.

4) It would be necessary at least to have the range of load resistance 200 ohm to 1000 ohm.

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Reference

1. Kaneko S, et al: Techniques and Significance of Electrical threshold measurement for Cardiac pacing. Artificial Organs(Japan), 6:396, 1977.
2. Smyth N, et al: The significance of electrode surface area and stimilating thresholds in permanent cardial pacing, J.Thorc.Cardiovasc. Surg. 71:559, 1976.
3. Barold S, et al: Techniques and Significance of Threshold Measurement for Cardiac Pacing, Chest, 70:760, 1976.
4. Luceri R, et al: Threshold Behavior of Electrodes in Long-Term Ventricular Pacing, Am.J.Cardiol., 40:184, 1977.
5. Furman S, et al: Cariac pacing and pacemaker IV. Threshold of cardiac stimulation, Am.Heart J., 94:115, 1977.
6. Parsonnet V, et al: Cardiac pacing and pacemaker VII. Power sources for implantable pacemakers. Part I. Am.Heart J., 94:517, 1977.