News on cardiac pacing, ICD and home heart monitoring

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CLINICAL IMPROVEMENTS BY DDDRP PACING IN PATIENTS WITH THE BRADY-TACHY FORM OF SICK SINUS SYNDROME

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With a prevalence rising with age from 0.05% at age 25-35 to more than 5% among people aged ≥ 69 years, atrial fibrillation (AF) and related atrial arrhythmias are the single most common sustained arrhythmia[1]. Once considered as a benign disease, AF is increasingly being recognized as a significant cause of morbidity and mortality.

Atrial tachyarrhythmias (AT) can be treated by a vast array of pharmaceutical and non-pharmacological therapies, suggesting that no single treatment is sufficiently simple, successful and cheap to exclude other therapies. Many new therapies are presently being developed, among which are electrical therapies that are designed to prevent and convert AT.

Drug therapy has poor long-term efficacy when used alone, with 50-70% of patients eventually progressing to chronic AT[1,2]. It also carries a risk for proarrhythmia and may increase mortality, especially in patients with left ventricular dysfunction[2,3].

Clinical experience indicates that in general a single-therapy approach (drug or ablation or device) is often associated with unsatisfactory results in the treatment of AT patients[1-12].

Several large randomized clinical trials have shown beneficial effects of physiologic dual-chamber pacing over ventricular pacing in terms of prevention of the development of AF in patients with bradycardia pacing indications and little AF at inclusion into the trial[13-17].

However, this benefit has been observed only after a relatively long follow-up, has been limited to the patients with sinus node dysfunction, and has not translated into improved survival. There is no evidence that conventional pacing from the high right atrium alone is effective in the control of AF in patients presenting with a high burden of AF but little or no bradycardia.

In general, randomized trials have shown a neutral or slightly positive effect of specific pacing algorithms in the prevention of AF in addition to physiologic pacing in patients with conventional bradycardia indications for pacing[18-24]. However, several subgroup analyses have suggested that these algorithms may be useful in selected AF patients, such as those with a low percentage of atrial pacing and frequent ABPs, with left atrial enlargement, and patients with relatively preserved atrioventricular conduction. Furthermore, there has only been a trend towards a reduction in AF burden and/or the frequency of AF episodes when pacing algorithms aimed at the suppression of triggers of the arrhythmia were used as adjuncts to bradycardia support pacing, dual-site or interatrial septal pacing.

It has been suggested that antiarrhythmic drugs may improve the efficacy of cardiac pacing in preventing AF, by increasing the percentage of paced beats and by impacting on the factors that initiate AF. Several non-controlled studies of this hybrid therapy approach have been reported[25,26].

Many authors have shown that antitachycardia pacing therapies are safe and effective in terminating supraventricular atrial arrhythmias. Efficacy has been measured in the range between 30 and 99%[27-33]. Recently the efficacy of pacing therapies in terminating AT and reducing AT burden has been proved in patients affected also by ven-

Table I.

	Baseline	DDDR	DDDRP
No. patients with symptomatic episodes (%)	45/45 (100%)	38/45 (84.4%)	30/45 (66.7%)
No. symptoms	2.2 ± 1.0	1.4 ± 1.2*	0.9 ± 0.8**
Quality of life	52 ± 15	64 ± 14*	69 ± 11**

* $p < 0.01$ vs baseline; ** $p < 0.01$ vs baseline and vs DDDR.

tricular arrhythmias and in patients affected by atrial arrhythmias associated with bradycardia[34-37].

An important issue is that the majority of trials available to date have excluded patients with advanced heart disease, e.g., congestive heart failure, making it unclear whether this vulnerable population might benefit from these therapies.

Dual-chamber implantable cardioverter-defibrillators and pacemakers with extended memory and more electrogram storage may allow more precise assessment of burden of the arrhythmia and the efficacy of atrial pacing therapies. It must also be appreciated that specific design of a randomized trial for atrial pacing studies may not be the ideal format to demonstrate the efficacy of a therapy that will probably only benefit a proportion of patients.

At present, there are only sparse data to recommend atrial pacing for the prevention of AF. However, every physician who has tried this type of therapy is aware of some dramatic successes as well as abject failures. So far trial data have been generally unhelpful even to aid identification of those who will respond to therapy. As yet, questions greatly outweigh answers in this important arena of clinical investigation.

Some interesting and encouraging results have been recently showed by the preliminary data from the PITAGORA trial, a 27-center prospective, randomized, single-blind study designed to evaluate the role of DDDRP pacing, based on prevention algorithms and antitachycardia pacing therapies, in preventing drug refractory paroxysmal AF in patients with sick sinus syndrome treated with class III vs IC antiarrhythmic drug therapy.

Since a few days the study completed the enrolment of the expected 180 patients. All patients with sick sinus syndrome and paroxysmal AF (at least three symptomatic episodes per year) were implanted with the Medtronic AT500™ pacemaker. At first month, patients were inserted into a single-blind crossover evaluation. Prevention algorithms and antitachycardia pacing features were programmed OFF in the first 4 months and ON in the following 8 months. At follow-up visits, performed every 4 months, quality of life EUROQOL questionnaire and Symptom Checklist questionnaire were submitted. Antiarrhythmic drug therapy was maintained stable after implant.

In the 45 patients who reached the thirteenth month of follow-up, and which were analyzed, the number of hospitalizations per year decreased from 1.9 ± 1.1 (pre-implant) to 1.0 ± 0.0 (post-implant, $p < 0.05$). Length of hospitalization decreased from 10.1 ± 8.1 (pre-implant) to 4.6 ± 6.8 days (post-implant, $p < 0.05$). Data about number of symptomatic patients, number of symptoms and quality of life are shown in table I[38].

In conclusion, the preliminary reports from the PITAGORA trial showed as prevention and antitachycardia pacing algorithms significantly reduced the number of patients with symptomatic episodes and the number of symptoms, furthermore significantly improved quality of life. Furthermore, in comparison with pre-implant, the number of hospitalizations per year and in-hospital stay significantly decreased post-implant, both demonstrating the clinical improvement in patients affected by sick sinus syndrome and treated by DDDRP pacing.

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IMPLANTABLE CARDIOVERTER-DEFIBRILLATOR HOME MONITORING TECHNOLOGY

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Implantable cardioverter-defibrillator (ICD) home monitoring is a new useful means to monitor ICD patients. The system, first used in Belos VR-T ICD (Biotronik, Berlin, Germany) allows us to obtain information on battery status, therapy history, shock efficacy, Holter ECG, pacing and clinical data. Up to now, there are only very few data which assess the efficacy of this monitoring system. The experience of our Center demonstrates that this new home-based monitoring system of ICD is safe, reliable, and easily manageable for patients. Home transtelephonic monitoring may be very useful to maintain closer ICD control, allowing a more frequent follow-up in patients with arrhythmic burden, and/or a reduction of routine controls in patients with stable clinical conditions. This home-based monitoring system is likely to improve the management of arrhythmic patients, while containing health costs and workload for cardiologists.

The expanding indications to implantable cardioverter-defibrillator (ICD) therapy, the growing complexity of devices, improvement of technology (i.e. rate-responsive sensors or resynchronization therapy), require careful attention to technical aspects, arrhythmias and clinical course of underlying disease of patients with ICD. This constitutes massive workload for cardiologists and electrophysiologic labs as well as high health care costs. Currently, a regular follow-up at 3 or 6-month intervals is usually performed, and allows us to obtain information on battery status, therapy history, shock efficacy, Holter ECG, pacing and clinical data. More frequent follow-up controls may be an excessive time-consuming workload for the implanting center, while a longer interval can delay the awareness of changes in the clinical status.

Even when a rigid follow-up scheme is applied unscheduled visits are bound to occur, i.e. after shocks or symptomatic arrhythmias. On the other hand, it is common experience during follow-up visits to recognize shocks or antitachycardia therapies delivered without patient awareness. Furthermore, in recent years important changes have been brought to ICD indications: secondary prevention as opposed to primary prevention indications, such as MADIT II criteria, require that some patients need to be followed more closely compared to others.

A new means to monitor ICD patients is offered by transtelephonic automatic transmission of ICD data. Transtelephonic monitoring is often used for pacemaker control, but frequently is dependent on the active cooperation of the patient, using a special device to connect the pacemaker and the telephonic network.

A new device developed for home transtelephonic monitoring (HTM) is easier to use and requires less patient cooperation: while the patient is asleep, the implanted ICD transmits automatically a periodic message to a device near to the patient, able to send by mobile or satellite network an encrypted message to a home monitoring service center. All information is immediately sent to the physician by fax or Internet. The first available HTM system for ICD is implemented on Belos VR-T (Biotronik, Berlin, Germany), a VVI rate-responsive ICD, connected with a specially adapted GSM telephone (RUCM 1000, Biotronik). Up to now, there are only very few data which assess the efficacy of this monitoring system.

Nine patients were implanted with Belos VR-T ICD in order to treat/prevent life-threatening arrhythmias, and were instructed on how to use the RUCM 1000 transmission device. The ICDs were programmed to transmit data every 24 hours on pacing impedance, paced/sensed percentage of ventricular rhythm, detection of arrhythmias and therapy eventually delivered, and battery status (Fig. 1). Mean follow-up was 99 ± 50 days (range 186-28 days). Out of 894 scheduled reports, failure of transmission occurred in only 18 cases (2%) due to mobile network reception defect or because the patient was not at home; in 1 case, the batteries of the mobile phone had run out.

During the scheduled follow-up, data obtained from HTM were compared with those recorded from the system programming device PMS 1000 (Biotronik): no differences were found in battery status, lead impedance, counts of episodes, and therapies delivered.

Furthermore, information obtained from the report allows us to monitor clinical data as well as to provide information on pharmacological therapy efficacy. As shown in figure 2, a reduction of sinus rhythm follows negative chronotropic therapy increase. Such monitoring may be useful to follow the evolution of the disease in patients who require different pharmacological treatments.

An important innovative step is the possibility of obtaining and visualizing data directly from Internet. In this way, immediate information from patients who present parameter modifications, will allow rapid management of eventual problems.

The experience of our Center demonstrates that this new home-based monitoring system of ICD is safe, reliable, and easily manageable for patients. HTM may be very useful to maintain closer ICD control, allowing a more frequent follow-up in patients with arrhythmic burden, and/or a reduction of routine controls in patients with stable clinical conditions. This home-based monitoring system is likely to improve the management of arrhythmic patients, while containing health costs and workload for cardiologists.

BIOTRONIK

CARDIO REPORT

Tel.: +49 9131 8924–300
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To attending physician	Dr. Tiziano Toselli Fax: +390532236593

Patient ID	Patient Device No.		
80040	SN 78601294	Last Message received at Patient Device	13.11.2003 at 01:14:53
		Last Message received at Service Center	13.11.2003 at 01:41:17
		Consecutive Report No.	157
	Implant / Serial No.	Consecutive Report: Date / Time	13.11.2003 at 02:16:10
	Belos A+/T / 79630040	Date of Preceding Cardio Report	12.11.2003 at 02:16:25

PERIODIC REPORT

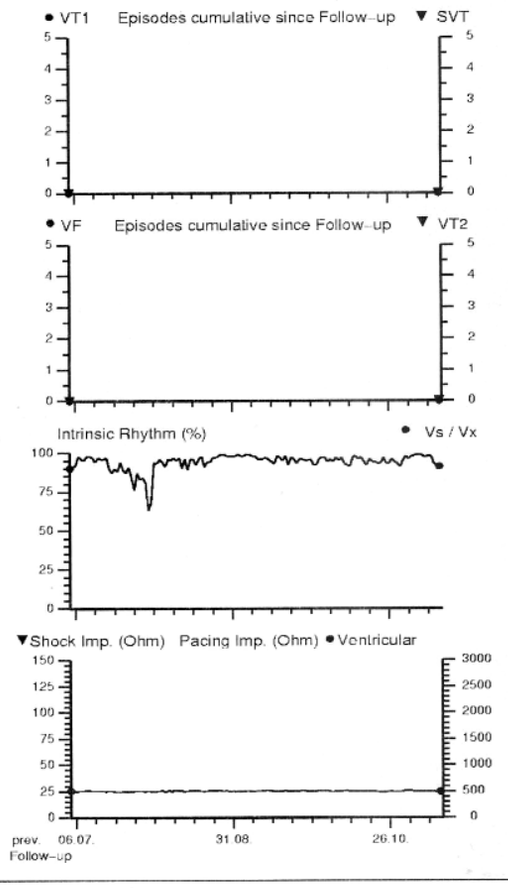
	Since last Follow Up 04.07.2003	Since Implantation
DETECTION		
Episodes in VT1 Zone	0	0
Episodes in VT2 Zone	0	0
Episodes in VF Zone	0	1
SVT	0	0
THERAPY		
ATPs started	0	0
ATPs successful	0	
Shocks started	0	1
Shocks successful	0	
Shocks aborted	0	0
30 J Shock without Success	0	

INTRINSIC RHYTHM* *Detection also during SVT	Since restart statistics	Since last Reporting Interval
Atrial senses (As/Ax) [%]		
Ventricular senses (Vs/Vx) [%]	94	91

BATTERY		
Status	BOL	
Voltage measured on	6.22 V	13.11.2003

LEADS	**Atrial**	**Ventricular**
Pace Impedance measured on		493 Ohm 13.11.2003
Shock Impedance measured on		59 Ohm 08.04.2003

DEVICE STATUS SUMMARY / REMARK	
Status	OK
Remark	



Monitoring Mode Settings	Monitoring Interval (periodic message from implant):	24 hours
	Reporting Interval between Follow Up (interval of periodic reports):	each message

Figure 1.

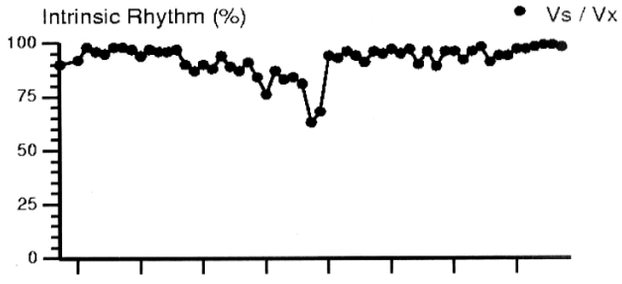


Figure 2.

PROGRESS IN BIVENTRICULAR PACING

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Background. **It seems that 10-20% of patients who undergo cardioverter-defibrillator implantation (ICD) require concomitant single- or dual-chamber pacing (DDD) for sinoatrial or atrioventricular conduction disturbances. Improvement of left ventricular function is one of the most important issues to decrease cardiac mortality in ICD patients.**

Methods. **We studied 110 patients who underwent biventricular (BV) device implantation with (n = 70) or without ICD back-up (n = 40) (BV pacemaker). In all patients, intraoperative electrophysiologic characteristics and long-term follow-ups were studied.**

Results. **Implantation of BV pacemaker was possible in 106/110 patients (96.3%). The mean time for BV device implantation was 175 ± 60 min and was not significantly different between BV ICD (186 ± 58 min) or BV pacemaker (154 ± 58 min) (p = NS). The mean radiation time was 41 ± 25 min and not significantly different between BV ICD (41 ± 26 min) or BV pacemaker (40 ± 24 min) (p = NS). During the mean follow-up, 14 patients died (12.7%). In patients with BV ICDs and BV pacemakers hemodynamic improvement was observed in 102/110 patients (92.7%). The QRS complex shortened significantly during BV with a mean QRS width of 140 ± 14 ms (range 110 to 180 ms) compared to a mean baseline QRS duration of 170 ± 32 ms (range 128 to 210 ms) (p < 0.05).**

Conclusions. **The introduction of BV pacing possibilities has led to more sophisticated patient management. ICDs with BV pacing are very promising devices to improve cardiac output, functional class of heart failure and may be decrease long-term mortality significantly. These new ICD developments may offer new hope for some patients with severe end-stage heart failure and life-threatening ventricular tachyarrhythmias.**

Introduction

Sudden cardiac death is one of the major causes of mortality in western countries with an incidence of approximately 450 000 victims per year in the United States and 100 000 sudden death patients per year in Germany[1]. Multiple pharmacologic and non-pharmacologic therapeutic options are currently available for the treatment of patients who have survived previous episodes of life-threatening ventricular tachyarrhythmias[2,3]. Disappointing results with antiarrhythmic agents, including class III drugs, as well as encouraging results from some implantable cardioverter-defibrillator (ICD) trials have led to non-pharmacologic alternatives gaining increased acceptance as a treatment for patients with this pathology[4-6]. Furthermore, subsequent to the introduction of the concept of the ICD, there have been many technologic innovations that have permitted vast improvements in therapy options and diagnostic features[7]. Technical innovations have allowed precipitous reductions in pulse generator volume and mass without sacrificing longevity or clinical effectiveness[8]. Recently, ICDs with dual-chamber pacing, sensors for rate-adaptive pacing and biventricular pacing possibilities have been introduced in clinical cardiology to allow atrioventricular and biventricular synchrony with an improved cardiac output[9,10]. Within the last years many studies have been published on the topic "biventricular pacing"[11-18].

Biventricular pacing

It has been shown in several studies that the outcome of ICD patients is clearly related to left ventricular dysfunction with the worst prognosis in patients with severe congestive heart failure (CHF)[19]. Prognosis and quality of life of CHF patients remain poor despite the use of ACE-inhibitors or beta-blocking agents supporting the use of non-pharmacologic therapies[20]. It has been proposed by several authors that electrical stimulation may be useful to improve cardiac output and functional class of heart failure as additional therapy in conjunction with pharmacological therapy[21,22]. Although early studies reported benefits of right ventricular pacing on hemodynamic findings, subsequent studies did not reproduce these improvements with similar CHF patients[23,24]. Consequently, the case of a patient in end-stage heart failure who improved dramatically after initiation of biventricular pacing introduced the concept of multisite pacing for patients with severe heart failure[25]. Recently, Auricchio et al.[26] reported that CHF patients with sufficiently wide surface QRS benefit from atrial-synchronous ventricular pacing; these authors described that left ventricular stimulation is required for maximum acute benefit.

Indications for biventricular pacing. It is well known from several studies that the outcome of ICD patients is clearly related to the degree of left ventricular dysfunction[20,27]. Patients who were considered for biventricular ICDs are those patients with ICD indications by general agreement (aborted sudden death, ventricular fibrillation, sustained monomorphic ventricular tachycardia) but with severe CHF (according to the NYHA functional classification) refractory to pharmacological treatment[27]. Some other criteria served as prerequisites for success biventricular pacing, particularly the width of the QRS complex (≥ 120 ms) (Table I).

Methods

Patient population. At our institution, devices with biventricular pacing possibilities were implanted in 110 patients (82 males, 28 females, mean age 63 ± 8 years, range 55-77 years). Coronary artery disease was present in 74 patients (67%), dilated cardiomyopathy in 27 patients (30%), and 9 patients (3%) had other underly-

Table I. Indications and prerequisites for implantable cardioverter-defibrillators with biventricular pacing possibilities.

Indications by general agreement
Cardiac arrest due to VF or VT
Spontaneous sustained VT
Syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at EPS
Indications as primary prevention
Non-sustained ventricular tachycardia in patients with prior myocardial infarction and left ventricular dysfunction and inducible VT or VF at EPS
Prerequisites for biventricular pacing
NYHA functional class III-IV
QRS width ≥ 120 ms in at least two surface ECG leads
PR interval ≥ 150 ms
CHF refractory to ACE-inhibitors, beta-blocking agents, diuretics

CHF = congestive heart failure; EPS = electrophysiologic study; VF = ventricular fibrillation; VT = ventricular tachycardia.

ing diseases. The mean left ventricular ejection fraction was 21 ± 2%. All our patients had suffered from at least one episode of aborted sudden cardiac death attributed to ventricular tachyarrhythmias and had severe CHF (NYHA class III-IV), refractory to medical treatment with ACE-inhibitors, diuretics, and beta-blocking agents as first choice as well as digitalis or calcium antagonists as additional drugs. These patients underwent biventricular ICD implantation (70 patients, 64%). There were 40 patients (36%) with severe CHF (NYHA class III-IV), refractory to medical treatment with ACE-inhibitors, diuretics, and beta-blocking agents as first choice as well as digitalis or calcium antagonists as additional drugs but without spontaneous or inducible ventricular tachyarrhythmias. These patients underwent biventricular pacing without defibrillation back-up.

Device implantation. In all patients, biventricular ICDs or biventricular pacemakers and leads were implanted under local anesthesia. The ventricular lead was placed at the right ventricular apex and the atrial lead was positioned in the right atrial appendage. After positioning of the two transvenous leads, the coronary sinus was introduced by a guiding catheter; thereafter, angiograms of the coronary sinus were performed in right anterior oblique 30° and left anterior oblique 60° projections. Using a guiding catheter the left ventricular pacing electrode (Easytrack®, Guidant CPI, St. Paul, MN, USA, Aescula® 1055 K or T, St. Jude Medical, Sunnyvale, CA, USA, Quicksite®, St. Jude Medical, Sunnyvale, CA, USA) was positioned in the left free wall. After evaluation of pacing parameters of the right atrial, left atrial (coronary sinus) and right ventricular electrodes defibrillation threshold testing was performed using a programmable stimulator/cardioverter-defibrillator/pacing analyzer with short acting general anesthesia (Hypnomidate® i.v.) in those patients who underwent biventricular ICD implantation. Ventricular fibrillation was induced by rapid ventricular pacing using an initial 20 J shock. If ventricular fibrillation was successfully terminated with 20 J, then additional testing was performed using progressively lower voltages in 5 J decrements until failure. The voltage was then increased by 5 J increments until two consecutive, successful conversions occurred; this voltage was defined as the defibrillation threshold and was considered adequate if there was at least a 10 J safety margin. At our institition, different biventricular pacing devices (Guidant Contak TR, Sude Jude Medical Frontier, Vitatron CRT 8000, Medtronic InSync III) or different ICD devices (Guidant Contak Renewal 2, Sude Jude Medical EPIC-HF, Medtronic InSync III Marquis) were used.

Results

Device implantation and electrophysiologic parameters. Biventricular ICD implantation or biventricular pacemaker implantation was possible in 106/110 patients. In 4 patients it was not possible to receive an acceptable coronary sinus position. The mean time for biventricular ICD implantation was 186 ± 58 min (range 123 to 284 min) and was not significantly different compared to the mean time for biventricular pacemaker implantation (154 ± 58 min, range 118 to 256 min, p = NS). The mean time to place the Easytrack® electrode was 113 ± 38 min (range 64 to 157 min). The intraoperative measurements showed a mean P-wave amplitude of 2.8 ± 1.2 mV (range 2.2-2.8 mV). The R-wave amplitude was 15.8 ± 6.7 mV (range 8.0 to 24.6 mV) with a pacing threshold of 0.8 ± 0.9 V (range 0.4 to 0.8 V) in the right ventricle and 15.8 ± 6.7 mV (range 7.4 to 17.6 mV) with a pacing threshold of 0.8 ± 0.9 V (range 0.6 to 2.9 V) in the left ventricle (p = NS). Ventricular fibrillation was induced in all patients with a mean defibrillation threshold of 15.4 ± 3.9 J (range 3 to 17 J). All values are listed in tables II-IV.

QRS width. In all patients, the 12-lead electrocardiogram was studied very carefully and the QRS width was compared during baseline, right ventricular or biventricular pacing. At rest, the mean QRS width was 170 ± 32 ms (range 128 to 210 ms) and did not change significantly when right ventricular pacing was performed (204 ± 23 ms, range 180 to 230 ms). However, the QRS complex shortened significantly during biventricular pacing with a mean QRS width of 140 ± 14 ms (range 110 to 180 ms).

Left ventricular dysfunction. The degree of heart failure was assessed according to the NYHA functional classification and by angiographically proven left ventricular ejection fraction. Prior to ICD implantation, all patients were in NYHA class III or IV. During the mean

Table II. Intraoperative measurements of patients with biventricular pacing devices.

No. patients	110
Age (years)	66.5 ± 8.06
Sensing RA (mV)	2.75 ± 1.18
Impedance RA (Ohm)	555.41 ± 134.83
Sensing RV (mV)	15.75 ± 6.69
RS-RV 0.5 ms (V)	0.76 ± 0.89
Impedance RV (Ohm)	636.70 ± 158.90
Sensing LV (mV)	15.35 ± 8.16
RS-LV 0.5 ms (V)	1.425 ± 1.09
Impedance LV (Ohm)	802.31 ± 236.50
Defibrillation threshold (J)	15.37 ± 3.96
HV interval (Ohm)	39.95 ± 6.44
Operation time (min)	174.62 ± 59.62
X-ray (min)	40.68 ± 24.76

LV = left ventricle; RA = right atrium; RV = right ventricle.

Table III. Intraoperative measurements of patients with biventricular pacemaker devices.

No. patients	40
Age (years)	67.74 ± 7.18
Sensing RA (mV)	3.22 ± 1.46
Impedance RA (Ohm)	601.37 ± 159.87
Sensing RV (mV)	17.78 ± 6.78
RS-RV 0.5 ms (V)	0.725 ± 0.38
Impedance RV (Ohm)	696.23 ± 171.53
Sensing LV (mV)	13.65 ± 8.02
RS-LV 0.5 ms (V)	1.50 ± 1.23
Impedance LV (Ohm)	907.22 ± 237.37
Operation time (min)	154.25 ± 57.76
X-ray (min)	39.74 ± 23.71

LV = left ventricle; RA = right atrium; RV = right ventricle.

Table IV. Intraoperative measurements of patients with biventricular implantable cardioverter-defibrillator devices.

No. patients	70
Age (years)	65.87 ± 8.49
Sensing RA (mV)	2.48 ± 0.91
Impedance RA (Ohm)	530.02 ± 112.22
Sensing RV (mV)	14.67 ± 6.42
RS-RV 0.5 ms (V)	0.78 ± 1.07
Impedance RV (Ohm)	603.54 ± 142.13
Sensing LV (mV)	16.37 ± 8.14
RS-LV 0.5 ms (V)	1.37 ± 1.00
Impedance LV (Ohm)	737.75 ± 213.176
Defibrillation threshold (J)	15.37 ± 3.96
HV interval (Ohm)	39.95 ± 6.44
Operation time (min)	186.27 ± 57.89
X-ray (min)	41.23 ± 25.54

LV = left ventricle; RA = right atrium; RV = right ventricle.

follow-up of 15 ± 13 months, 7 patients died from CHF (6.4%), 5 patients (4.5%) died suddenly. There were 1/70 patient (2.9%) who died with an implanted biventricular ICD; all patients died from CHF. There were 12/40 patients (25.5%) who died with an implanted biventricular pacemaker: 5 patients died from CHF and 4 patients died suddely.

Complications. ICD implantation was possible without any problems and perioperatively we did not observe any complications. One patient with extensive anticoagulation developed pocket hematoma (no surgical intervention required), all other patients were doing fine. Patients were discharged with a mean of 6 ± 5 days (range 3-14 days) after implant and predischarge electrophysiologic testing. During follow-up, dislocation of any of the electrodes occurred in none of the patients.

Discussion

CHF is one of the most important healthcare problems in the world, afflicting approximately 2-4 million people in the United States and nearly 15 million people worldwide[30]. Mortality from CHF remains high and sudden death is a major threat to CHF patients[31]. In 1997, we could demonstrate in 410 patients, that the incidence of sudden death is low in ICD patients independent of the degree of left ventricular dysfunction with excellent survival rates of > 90%. However, cardiac and total mortality was relatively high in patients with NYHA class III compared to those with NYHA class I and II[19].

There is no question that biventricular pacing is a very promising approach to treat patients with severe heart failure[32]. However, at the present time only few study results are available and the role of biventricular pacing in ICD patients is unclear[33]. Despite first very promising results to improve cardiac output and left ventricular function, some technical problems are present: although we could demonstrate that implantation of biventricular ICD devices was possible without any problems, the implantation time was relatively long compared to a single-chamber ICD implantation[27]. Therefore, one of the most important steps to improve the implantation procedure is to develop guiding catheters for intubation of the coronary sinus with an acceptable back-up to introduce the Easytrack® electrode more easily. In addition, at the present time the ideal site for left ventricular pacing is unanswered: Blanc et al.[34] studied different pacing sites in 23 patients with severe CHF and could demonstrate that left ventricular pacing alone and biventricular pacing resulted in similar hemodynamic improvements, whereas the hemodynamic effect of right ventricular pacing alone was low. Cazeau et al.[35] studied multiple pacing site in 8 patients and concluded that biventricular pacing was associated with a rapid and sustained hemodynamic improvement. However, to the best of our knowledge no confirmed data are available about the ideal site of left lateral free wall

pacing and no data are present to show the best part of the coronary sinus tree for definite left ventricular pacing.

The outcome of patients with biventricular pacing modalities was acceptable in our small patient population and confirmed clinical results of improved left ventricular function in patients with severe CHF[32-34]. However, these data are mainly observed during short-term follow-up and, of course, not representative for all patients with poor left ventricular function[35]. Therefore, further studies with larger patient populations and longer follow-up periods are necessary to confirm or reject the preliminary excellent results of biventricular pacing in patients with severe CHF. In addition, further observations are necessary to study the mechanisms of biventricular pacing and to evaluate the role of biventricular resynchronization.

Clinical implications. ICDs with biventricular pacing possibilities are very promising devices to improve cardiac output, functional class of heart failure and decrease long-term mortality significantly. It seems that multisite pacing improves the efficacy of pump function in patients with severe heart failure and conduction system disease. However, the acute hemodynamic changes that were reported do not necessarily guarantee that either long-term hemodynamic improvement or a clinically apparant benefit will be sustained. Nevertheless, the data from recently published studies suggest that chronic biventricular pacing incorporated in an ICD may offer new hope for some patients with severe end-stage heart failure and life-threatening ventricular tachyarrhythmias.

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HOLTER RECORDING OF ECG AND RESPIRATION IN CHRONIC HEART FAILURE. CLINICAL ROLE OF A NEW TELEMONITORING TECHNIQUE

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Nocturnal respiratory disorders and depressed heart rate variability are known predictors of poor prognosis in chronic heart failure patients. Intermittent monitoring of cardiorespiratory signals while the patient is at home might thus allow early identification of clinical deterioration and prompt optimization of treatment, leading to reduced hospitalizations and mortality and improved quality of life. Within the European Community multicenter trial HHH (Home or Hospital in Heart Failure), we are testing a novel low-cost system for 24-hour recording of cardiorespiratory signals, suitable to be self-managed by the patient at home, with transmission of acquired data through standard telephone lines to the medical/nursing staff. Preliminary results from 24 patients with chronic heart failure enrolled so far indicate that monthly home telemonitoring is feasible and the compliance is high.

Introduction

Periodic breathing, a respiratory disorder characterized by cyclic phases of hyperventilation separated by hypopnea or apnea, occur very frequently in patients with chronic heart failure (CHF)[1,2]. Recent studies on periodic breathing report a prevalence as high as 64 and 70% during respectively awake laboratory recordings and sleep studies[3]. Periodic breathing is accompanied by cyclical reductions in arterial oxygen saturation and by marked fluctuations of systolic and diastolic pressure and heart rate. Periodic hypoxemia causes an increase in sympathetic activity which may contribute to the occurrence of fatal arrhythmias and cardiotoxicity. Moreover, hyperventilation and the increased work of respiratory muscles place an increased demand upon the already failing heart, thus contributing to left ventricular dysfunction. In addition, the reduced amount of sleep brought about by frequent arousals causes fatigue and excessive daytime sleepiness. It is thus not surprising that recent studies have shown that CHF patients with severe periodic breathing have a reduced life expectancy[4].

Many studies on heart rate variability (HRV) either during long-term (24-hour) or short-term (< 10 min) recordings have consistently shown that HRV indexes provide independent prognostic information on mortality in CHF patients[5,6].

One of the aims of the European Community multicountry study HHH (Home or Hospital in Heart Failure, QLGA-CT-2001-02424) is to evaluate in the home setting a new system for long-term non-invasive cardiorespiratory and activity monitoring (NICRAM), suitable to be self-managed by the patient, with transmission of acquired data through standard telephone lines to the medical/nursing staff. For each patient, data are being collected once per month during an entire year. We expect these data to provide important information on: a) the prevalence, pattern and natural history of breathing disorders recorded during prolonged observational periods (more than one night or one day), and their relationship with the outcome, including clinical instabilization; b) the clinical impact of simple treatment strategies aimed at suppressing periodic breathing (oxygen + theophylline); c) the prognostic value of abnormal (i.e., markedly reduced) HRV with particular regard to hospital readmissions.

Methods

The NICRAM recorder. The NICRAM recorder used in the HHH study is a Holter-style portable device

(Report-24, FM, Monza-MI, Italy) capable of recording 24 hours of ECG (single lead), respiration (bioimpedance technique), body movement (by an accelerometer), body position and events. The device has been adapted to the specific needs of the HHH project through a strict cooperation between our group and the manufacturing company. The recorder is suitable to be easily handled by the patient at home and has the capability of being connected to a specialized modem device (see below) to transmit acquired data to the medical/nursing staff in the enrolling hospital.

Three ECG electrodes are used to pick up both the ECG and the respiratory signal, while a small plastic box fastened on the patient's upper thorax by a piece of tape houses the body movement and position sensors. All the wires from the electrodes and the sensor box converge to a unique cable plugged into the recording device. The signals are acquired at different sampling frequencies: 250 Hz for ECG, 10 Hz for respiration, and 1 Hz for the movement and position signals. The movement signal is derived from the raw accelerometer signals. As the two pick-up electrodes are used both for the ECG and the respiratory signal, an electrode position optimization procedure is usually required to find the best trade-off in the two signals quality. To this purpose, acquired signals can easily be inspected on a PC screen using a telemetry connection. The optimization procedure is carried out by the nurse at enrolment of the patient into the telemonitoring program and the digital picture with the optimal electrode positioning is then printed into the personalized user manual given to the patient before going home.

The recorder is also capable of performing a real-time preprocessing of the ECG signal to derive the corresponding RR time series. One lamp flashes at each detected QRS complex, while two other lamps signal the inspiration and expiration phases. Events can be recorded by pressing a button. All signals are continuously recorded on a solid state memory support (flash card, 32 MB).

The Smart Modem. After completion of the 24-hour NICRAM recording, the recorder is connected by the patient to a Smart Modem developed by a company member of the HHH consortium (Appel Elettronica, Turin, Italy). Data downloading (RR + respiration + movement/position) from the recorder to the Smart Modem memory buffer starts automatically after the connection. After completion of downloading, the Smart Modem carries out automatically the following tasks: a) dialing the receiving station (IVR) located in the national coordinating center, b) setting up a standard modem connection, c) sending the patient ID, d) transmitting NICRAM signals, e) managing all transmission problems, including restarting the transmission in case of communication failure. All received data are copied by the IVR into the study database (country database).

Signal quality check and analysis. Each newly received NICRAM recording is first checked by the signal analyst in order to assess signal quality. A NICRAM recording is judged as not acceptable by the signal analyst when a) the respiratory signal or the RR signal are absent (due for instance to electrode misconnection) or b) when either of them does not satisfy the quality criteria defined in the guidelines of the study. A respiratory signal is defined as being of good quality when the signal-to-noise ratio is high enough to allow the signal analyst to reliably classify breathing activity (phasic, periodic or artifact) and detect abnormal respiratory events (hypopneas and apneas).

The RR signal is defined as being of good quality if its trend is compatible both in value and pattern with known human physiology and pathophysiology and there is a low rate of false detections and missing beats. Should the quality be poor, the patient will be asked to repeat the recording (for a maximum of 2 times).

The analysis of respiratory recordings provides a set of standard and non-standard quantitative indexes of breathing disorders developed by the patient during the day, the night and the overall 24-hour period. They include a) the duration of periodic breathing, b) the total number of recognized apneas, c) the apnea prevalence, d) the apnea index and the apnea/hypopnea index.

The analysis of RR time series is carried out interactively on consecutive 5 min segments and provides a set of standard quantitative indexes of HRV, in the time and frequency domain, for the overall 24-hour period as well as for day-time and night-time epochs. Final indexes are average measurements across all analyzable segments.

A report containing cardiorespiratory indexes as well as an uncalibrated physical activity score is a) sent to the patient's enrolling center and b) saved permanently into the country database.

Results

The HHH study is currently in progress in the three European countries involved in the project (Italy, UK and Poland). *Ad interim* results on the feasibility and patient's compliance of home telemonitoring of NICRAM signals are now available for Italy, where 24 patients have been enrolled so far. Out of 130 scheduled recordings, 123 (95%) were actually feasible, being the patient alive and at home. Among them, 122 (99%) were actually carried out by the patients. Transmission of these recordings by means of the Smart Modem failed in 22 (18%) cases, due to patient error (46%), technical problems (18%) or organizational reasons (36%). Yet, most (91%) of non-transmitted recordings were recovered by direct downloading of signals from the recorder. The final number of recordings available for analysis was 120 (98% of feasible recordings). One hundred and three respiratory recordings (84% of feasible recordings) were considered

eligible for the study (> 2.5 hours of good quality data during the night), while 67 (56%) recordings satisfied the eligibility criteria for HRV (> 5 hours and > 2 hours of analyzable data during the day and night respectively). This eligibility rate for HRV is only slightly lower than the one we have observed (67%) in a large sample (n = 510) of edited and annotated RR time series from a commercial Holter system.

Conclusion

These preliminary results indicate that monthly 24-hour home telemonitoring of cardiorespiratory signals based on self-management of recording and transmitting devices is feasible in CHF patients and the compliance is high.

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