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Do Adaptors Shorten the Battery Life of Nonrechargeable Generators for Deep Brain Stimulation?

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■ OBJECTIVE: **Generators implanted for deep brain stimulation must be replaced after several years. If a Kinetra generator is replaced by the Activa-PC, an adaptor will be required to attach it to the original extension cables. On the basis of our clinical impression that the battery life of the Active-PC generator was shorter when an adaptor was used, we performed this retrospective study.**

■ METHODS: **We determined the battery lifetimes of deep brain stimulation generators that had been implanted in our department. The inclusion criterion was the initial implantation of a Kinetra generator that was later replaced by an Activa-PC with adaptor, which itself was subsequently also replaced. These patients were compared with an Activa-PC control group without an adaptor but identical with regard to number of battery exchanges, disease, and target.**

■ RESULTS: **There were 28 patients in the study group and 14 in the control group. Battery lifetime of the Activa-PC with adaptor (32.4 ± 7.7 months) was significantly shorter than that of the Kinetra (53.5 ± 15.7 months, $P = 0.000006$). The battery life of Activa-PC without an adaptor (35.3 ± 8.2 months) did not differ significantly from that of the Activa-PC with an adaptor ($P = 0.333$).**

■ CONCLUSIONS: **The battery lifetime in a replacement Activa-PC is shorter than that in the original Kinetra generator. Adaptors have no significant effect on battery life. Patients should be informed that the battery in their new generator must be checked more frequently than before.**

INTRODUCTION

Deep brain stimulation (DBS) is an accepted standard therapy for movement disorders, such as Parkinson disease (PD), essential tremor, or dystonia, which markedly improves motor outcome and quality of life.[1-3]

Until 2008 only nonrechargeable generators were available. Since then, Medtronic (Dublin, Ireland), the sole provider of generators at that time, has replaced its earlier model, Kinetra, with the rechargeable generator Activa-RC and the nonrechargeable generator Activa-PC. Until recently we usually implanted nonrechargeable generators,[4-8] which necessitated an exchange of the impulse generator after several years. After Kinetra was taken off the market, an adaptor was required to connect the successor model, Activa-PC, to the old model extension cables and electrodes. We have shown previously that the battery lifetime in the Activa-PC is shorter than that in the Kinetra generator,[9] but we also had the impression that the battery lifetime in the Activa-PC with an adaptor was even shorter than in the Activa-PC generator without an adaptor.

The main objective of this study was to compare the battery lifetimes of the models Kinetra and Activa-PC with and without an adaptor.

METHODS AND PATIENTS

The study was approved by our institution's ethics committee. We retrospectively determined the battery lifetimes in 28 patients suffering from PD, dystonia, or tremor, in whom DBS electrodes and generators had been implanted in our department. Until the end of 2008, Kinetra generators were used exclusively, and in 2009 our department started implanting the successor model, Activa-PC. The Activa-PC generator requires an adaptor for connection to the older extension cables.

Key words
- Activa-PC
- Adaptor
- Battery life
- Deep brain stimulation
- IPG
- Kinetra

Abbreviations and Acronyms
DBS: Deep brain stimulation
PD: Parkinson disease
TEED: Total electrical energy delivered

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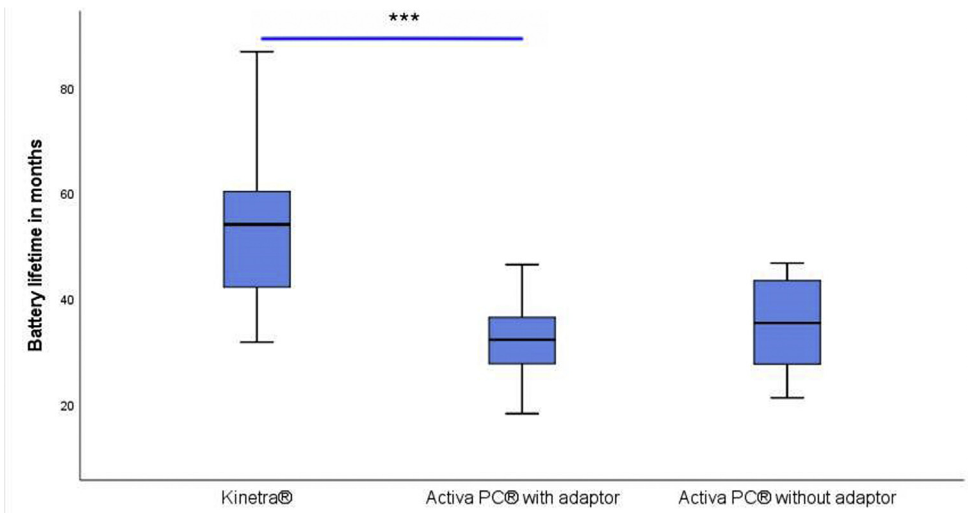

Figure 1. Battery lifetime of Kinetra ($n = 28$), Activa-PC with adaptor ($n = 28$) and Activa-PC without adaptor ($n = 14$). *** $P < 0.01$.

All patients were stimulated bilaterally, targeting the subthalamic nucleus, ventral intermediate nucleus of the thalamus, or globus pallidus internus. An inclusion criterion was tonic (i.e., continuous stimulation). All generators were exchanged in ERI mode according to the manufacturer's guidelines.The lifetime of the battery was measured as the time from implantation until explantation, provided that a low-energy status was the reason for explantation.

Battery lifetimes in this group were compared with those in a control group of patients with an Activa-PC generator but without an adaptor. The patients were identical with regard to number of exchanges, underlying disease, and target.

Battery lifetimes before and after the exchange in the study group were compared by Mann-Whitney-U-test for paired data (SPSS Version 22). A Wilcoxon test was used to compare lifetimes in the study and control groups.

In order to compare the stimulation parameters before and after exchange, we calculated the total electrical energy delivered (TEED) without impedance as impedances were not available in all patients before and after exchange. For calculating the TEED, the following formula was used:

TEED = (amplitude [V] ^{2}* frequency [Hz] * impulse width [s]/ impedance [Ω]) * 1 second.[10]

RESULTS

Of the 34 patients in whom a Kinetra generator was replaced by an Activa-PC generator and connected to the indwelling cables with an adaptor, 28 patients fulfilled the inclusion criteria. Of these, 24 were suffering from PD and 4 from dystonia. Eleven patients were female and 17 were male. Mean age at change to Activa-PC with adaptor was 65.4 years ranging from 47–79 years.

Our control group had 14 patients: 12 with PD and 2 with dystonia. Mean age was 64 (range 51–81) years. The groups were matched for the number of exchanges, disease, and target. In 6 patients of the study group the exchange from Kinetra to Activa-PC with an adaptor was the second exchange. In the remaining 22, it was the first exchange. In our control group the measured battery life was that after the second exchange in 3 patients and after the first exchange in 11.

The mean battery life of the Kinetra generator before replacement was significantly longer (53.5 ± 15.7 months) than that of the Activa-PC with an adaptor (32.4 ± 7.7 months) (P = 0.000006). The battery life of Activa-PC without an adaptor (35.3 ± 8.2 months) did not differ significantly from the battery life of the Activa-PC with an adaptor (P = 0.333). **Figure 1** shows the battery lives of Kinetra and Activa-PC with and without adaptors.

In a second step we calculated the TEED without impedance. **Table 1** shows data before and after exchange for 25 patients. In 3 patients, stimulation parameters were missing.

DISCUSSION

The lifetime of the batteries incorporated in DBSs is of great importance for the patient, as every battery change can increase the risk of infection,[4] and the treatment costs for society are mainly influenced by the lifetime of the stimulators.[11] Our previous study demonstrated a significantly shorter battery life of the Activa-PC generator compared with the Kinetra, which has been confirmed in another cohort.[12,13]

In the current investigation we confirmed the significantly shorter battery lifetimes for the Activa-PC replacement generator with adaptor compared with the initially implanted Kinetra. Since the required stimulation amplitude increases

Table 1. Battery Lifetime and Total Electrical Energy Delivered/Impedance in 25 Patients Before and After Exchange

Patient Number	Battery Life Span in Months Before Replacement	Battery Life Span in Months After Replacement	TEED Without Impedance Before Replacement in mW*Ω	TEED Without Impedance After Replacement in mW*Ω
1	47	33	230	194
2	38	28	98	270
3	48	28	364	346
4	61	33	249	249
5	60	35	218	218
6	43	19	313	327
7	60	36	250	250
8	32	23	250	346
9	37	27	328	196
10	79	18	400	419
11	42	25	365	366
12	58	31	346	346
13	62	30	222	245
14	40	28	517	529
15	61	38	219	185
16	51	35	282	214
17	55	46	166	166
18	36	30	463	427
19	47	37	240	194
20	38	32	292	278
21	43	45	142	119
22	92	61	271	171
23	87	30	267	168
24	65	35	280	215
25	60	46	129	134

during disease progression, this finding is not surprising as the patients with a generator replacement will have been stimulated for a longer period and will probably need a higher stimulation current. To prove this theory, we compared the mean TEED without impedance of this work before exchange (276 mW * Ω) and after exchange (263 mW * Ω) with our former study: 220 mW * Ω for the Kinetra group and 145 mW * Ω for the Activa-PC.

We were unable to detect a significant difference in the battery lifetimes with and without adaptors and would therefore tend to hold higher stimulation parameters responsible for the dramatically reduced battery life after an exchange from Kinetra to Activa-PC. However, one cannot exclude the possibility that the battery in the Activa-PC has a lower capacity than that used in the Kinetra. A further possibility is that the Activa-PC reaches the ERI mode with a higher residual capacity compared with the Kinetra.

Due to the shorter battery lifetime in the replacement device, battery monitoring must be performed more frequently, and the patients must be informed that their new device will have a shorter lifetime than the previous model.

CONCLUSION

Battery lifetime of Activa-PC generators is not shortened by the use of an adaptor. We further conclude that frequent monitoring of battery status is essential, as the battery lifetime of the replacement Activa-PC is shorter than that of the initially implanted Kinetra.

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