



## ORIGINAL ARTICLE

# Do kidney transplantations save money? A study using a before–after design and multiple register-based data from Sweden

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## Abstract

**Background:** The health care costs of kidney transplantation and dialysis are generally unknown. This study estimates the Swedish health care costs of kidney transplantation and dialysis over 10 years from a health care perspective.

**Method:** A before–after design was used, in which the patients served as their own controls. Health care costs the year before transplantation were assumed to continue in the absence of a transplant and the cost savings was therefore calculated as the difference between the expected costs and the actual costs during the 10-year follow-up period. Factors associated with the size of the cost savings were studied using ordinary least-squares regression.

**Results:** Altogether 66–79% of the expected health care costs over 10 years were avoided through kidney transplantation, resulting in a cost savings of €380 000 (2012 price-year) per patient. Savings were the highest for successful transplantations, but on average the treatment was cost-saving also for patients who returned to dialysis. No gender or age differences could be found, with the exception of a higher cost of transplantation for children and a generally higher cost for younger compared with older patients on dialysis. A negative association was also found between age at the time of transplantation and the size of the cost savings for the younger part of the sample.

**Conclusion:** Kidney transplantations have led to substantial cost savings for the Swedish health care system. An increase in donated kidneys has the potential to further reduce the cost of renal replacement therapy.

**Key words:** dialysis, health care costs, kidney transplantation, Sweden

Received: February 24, 2017. Editorial decision: June 12, 2017

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## Introduction

Human organs for transplantation are scarce in Sweden, as in the rest of the world. Alternatives to transplantation are lacking and it is generally only patients with kidney failure who have a reasonable alternative, i.e. dialysis. However, kidney transplantation is the preferred renal replacement therapy (RRT) due to improved quality of life and health-related outcomes compared with dialysis [1, 2]. The shortage of kidneys available for transplantation limits the number of patients who are able to take advantage of this treatment. This is mainly because too few potential donors are identified. Extensive efforts have been made to increase the number of donors, but the shortage remains. It is therefore important to have a clear understanding of the costs and benefits of transplantation to determine whether interventions to increase available kidneys are worth the cost.

Little is known about the cost of kidney transplantation over time [3]. Figures frequently quoted in the Swedish debate are that the health care costs for kidney transplantation are ~ €115 000 over 10 years, while the corresponding cost for dialysis is said to sum to €460 000–800 000. These numbers are of unclear origin; also, they have figured in the debate for a relatively long time and are probably outdated because of improved technological and medical treatment. Chamberlain *et al.* [4] estimated the cost for the first 3 years after transplantation in Sweden to be €44 000–68 000. In Belgium, the 1-year post-transplant health care cost including surgery has been estimated at €40 000 [5], while the first- and second-year post-transplant costs in Germany have been estimated at €34 000 and €14 000, respectively [6]. A French single-centre study estimated the cost of the hospital stay for kidney transplantation to be €14 000 [7].

Previous studies are generally descriptive in their costing approach in that no comparisons are made with the expected health care cost in the absence of transplantation. The follow-up time is also limited to 1 year, or at most a few years [4–7]. An exception to this is a UK study that found the total in- and outpatient cost of kidney transplantation, excluding the transplantation surgery, to be €9600 in the first year and decreasing gradually to €2600 in the sixth year after transplantation. Kidney transplantation compared with haemodialysis (HD) was estimated to result in cost savings of ~75% in the first 4 years post-transplantation [3].

The purpose of this study was to estimate the health care costs in Sweden of kidney transplantation and dialysis over 10 years from a health care perspective stratified for gender and age and to estimate the expected cost savings of transplantation. We also investigated which factors are associated with the effectiveness of kidney transplantation. This study contributes to our understanding of longer-term outcomes and costs by using a longer follow-up time and through comparison with a counterfactual situation using the transplanted patients as their own controls in a before–after approach.

## Materials and methods

Patients on RRT were identified through the Swedish Renal Register, which has a coverage of >95% [8] and close to 100% for transplanted patients [9]. This register has been linked to data on health care utilization and costs from the Region Skåne and Stockholm County, two of the largest health care administrative areas in Sweden, corresponding to ~35% of the Swedish population.

Transplanted patients are not representative of all patients on RRT and therefore we could not use patients on dialysis as a control group. Instead, transplanted patients were used as their own controls and a before–after design was employed. The cost of health care utilization in the year before transplantation was assumed to continue in the absence of a transplant. Any cost reduction after transplantation, compared with the year before, was attributed to the kidney transplantation. The validity of this assumption will be discussed based on the development over time of costs for patients on dialysis, which will therefore also be analysed.

Patients who started RRT treatment (dialysis or deceased- or living-donor transplantation) during 1998–2012 were included in the study. Five patients lacking information on current treatment (lost to follow-up) and 15 patients for whom cost information was lacking during the year of transplantation/dialysis were excluded, leaving a sample size of 4680, of whom 1220 received transplantation. Due to missing health care costs, the sample of transplantation patients was reduced to 1081 in the cost analysis.

The total health care cost for the year of the transplantation was calculated. This year was defined to have started 8 days before the date of transplantation to capture the full inpatient episode related to the transplantation. Costs for each year, up to 10 years before and 10 years after the year of transplantation, were calculated for each full year until death or until the end of the study period. For patients who died during the study period, only the last full year was included in the analysis, calculated from the date of transplantation or start of RRT (a sensitivity analysis was performed to calculate the health care cost during the last year of a patient's life based on their date of death). In the analysis, the number of years differed between patients and the sample size was thus reduced with each additional year of follow-up. An alternative approach was also used in which only the costs occurring while on RRT were included. In other words, using left censoring of the costs before transplantation, the 'before' observations were reduced and all patients who initiated RRT with a transplantation were excluded.

Patients on dialysis were treated in the same manner as transplanted patients, but we used two different starting points: start of RRT and an adjusted start of RRT based on the average time patients in the sample had to wait for a transplant (625 days) (for both groups, the starting point was calculated in relation to the start of RRT; the left-censoring approach cannot be used for dialysis). The latter starting point allows the cost of dialysis to change over time in treatment, e.g. through complications, better representing the counterfactual situation for transplanted patients. All costs were adjusted to the price level of 2012 using the Swedish consumer price index.

As well as analyses stratified by gender, age and transplantation type, three subgroup analyses based on graft outcome were performed: (i) functioning graft during follow-up, (ii) return to dialysis during follow-up and (iii) additional transplantation during follow-up. The average health care cost for the transplantation and dialysis episodes was calculated, based on the *International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10)* diagnosis and activity codes KAS10, KAS20, DR014, DR015, DR016, DR017, DR024, Z491 and Z492. The *t*- and  $\chi^2$ -tests were used to examine differences between groups.

An ordinary least-squares (OLS) regression was run on the cost savings of transplantation during the first year after transplantation. This was done in order to identify factors associated

**Table 1.** Comparison between transplanted patients and patients on dialysis in the study sample from Region Skåne and Stockholm County and patients in the rest of Sweden

	Transplantation		Dialysis	
	Study sample (n = 1220)	Rest of Sweden (n = 2855)	Study sample (n = 3460)	Rest of Sweden (n = 8684)
Women (%)	34	37	35	34
Age at start of RRT (years)	45.5	46.5	69.2	69.8 <sup>a</sup>
Start date of RRT (mean)	4 February 2005	16 December 2004	23 July 2005	14 June 2005
Tx date (mean)	16/10/2006	10/8/2006		
Number of risk factors	1.1	1.2	2.1	2.1
Waiting time for Tx (days)	627	610		
Patient deceased (%)	14	15	87	87
Treatment at follow-up: HD (%)	8	8	81	80
Treatment at follow-up: PD (%)	1	1	19	20
Treatment at follow-up: Tx (%)	91	91		
Number of Tx's	1.05	1.06		
Total time in HD (days)	506	465	825	812
Total time in PD (days)	248	261	226	231
Total time with transplant (days)	2450	2524		
Total time on RRT (days)	3211	3258	1059	1055

<sup>a</sup>Statistically significant differences between patients in the sample and patients in the rest of Sweden, at the 5% significance level. HD, haemodialysis; PD, peritoneal dialysis; Tx, transplantation.

with the effectiveness of transplantation in terms of cost savings.

Stata version 13 (StataCorp, College Station, TX, USA) was used for all statistical analyses. This study was approved by the Lund Regional Ethical Review Board, Lund, Sweden (dnr: 2014/144).

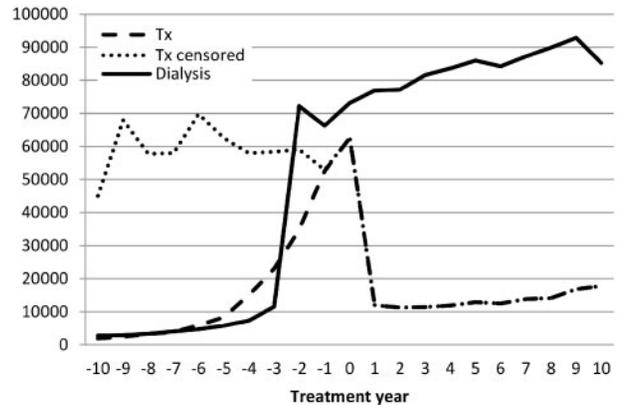
**Results**

Table 1 compares patients included in this study with patients in the rest of Sweden, indicating that the sample is representative for the whole of Sweden. Within-sample comparison shows large differences between transplanted and dialysis patients. This implies, as expected, that these two groups should not be compared directly.

**Health care costs for patients on RRT**

Figure 1 shows the average health care cost in the year of transplantation (year 0) and the preceding (years -1 to -10) and post-transplantation (years 1-10) periods. Figure 1 shows a rapid rise in cost until year 0. After an initial cost increase of €10 000 at year 0, compared with year -1, the cost fell rapidly in year >0. The average cost fell by 77% during the first year after transplantation (year +1) (Table 2) and then remained relatively stable, only to start increasing in post-transplantation year 7. We found large cost differences between patients and several genuine outliers increased the average cost. The average cost during year <0 for transplant patients on RRT (censored) was markedly higher compared with the transplant group in general. However, it did not affect the cost savings of transplantation as the costs converged around year -1. Altogether 173 transplant patients passed away during the follow-up, with an average last life-year health care cost of €83 000 (median €32 000).

The corresponding costs for patients on dialysis are also shown in Figure 1, where year 0 is the start of RRT, adjusted for average waiting time for a kidney among transplanted patients. One peak can be noted 2 years before the adjusted start of RRT (i.e. at the actual start of RRT), which is probably related to high



**Fig. 1.** Health care costs in euros (€) per patient and year for patients on RRT. Year 0 = the year of transplantation or the first year on RRT, plus 625 days for patients on dialysis (625 days corresponds to the average waiting time for a transplant in the sample).

initial costs due to an acute phase of the disease. The health care cost during the last life year among dialysis patients was estimated at €86 000 (median €81 000), which corresponds to the expected cost of a patient after a few years of dialysis (Figure 1).

**Age, gender and transplantation type stratification**

Comparing younger [mean age 42 (range 1-57) years] with older [mean age 67 (range 58-85) years] transplanted patients showed significantly higher health care costs for older patients in the year <0 but not the years 0 or >0. Transplanted children (<16 years of age), however, had substantially higher health care costs in the years 0 and >0 compared with adults. The average costs for year 0 for patients <16 years of age were €115 000 per patient, which is about twice as high as for adults (only two children <16 years of age were defined as dialysis patients in the sample, the reason why a cost comparison between children and adults could not be made). For patients on dialysis, significantly higher health care costs were calculated for younger [mean age 63 (range 0-74) years] compared with older [mean age 81 (range 74-97) years] patients in years <0, 0 and 1-5 after the start of RRT

Table 2. Health care cost savings over 10 years due to kidney transplantation

Year	Observations (n)	Cost, (€) (SD)	Expected cost in the absence of transplantation (€) <sup>a</sup>	Cost savings (€) <sup>b</sup>	Proportion saved (%) <sup>b</sup>
0	1081	62 551 (73 229)	52 476	-10 076	-19
+1	960	11 938 (27 669)	52 476	40 537	77
+2	847	11 258 (29 696)	52 476	41 218	79
+3	738	11 390 (27 561)	52 476	41 085	78
+4	638	11 838 (25 898)	52 476	40 638	77
+5	528	12 870 (35 853)	52 476	39 606	75
+6	445	12 478 (26 107)	52 476	39 997	76
+7	357	13 808 (33 050)	52 476	38 667	74
+8	277	14 077 (29 665)	52 476	38 398	73
+9	212	16 839 (36 636)	52 476	35 636	68
+10	139	17 834 (30 583)	52 476	34 642	66

<sup>a</sup>Expected cost corresponds to health care cost the year before transplantation [standard deviation (SD) = €53 407].

<sup>b</sup>Note that a negative value means a higher cost compared with the expected cost.

(Figure 2). Stratifying for transplantation type [deceased-donor (57%) or living-donor (43%) transplantation] showed lower health care costs post-transplantation for living-donor transplantation. However, the difference was only statistically significant for every second year, indicating no trend (data not shown). Gender differences were only found for a few random years before the start of dialysis/transplantation and are therefore not reported further.

### Outcome stratification

Patients who received an additional transplant during the study period were younger (average 49 years old) compared with other transplant patients (54 years old for successful transplantation and 56 years old for return to dialysis), while the mortality rate was higher among patients who returned to dialysis (29% versus 13% for the other two groups).

The average health care costs for successful transplants (85% of the total number of transplants) had a similar development as with all transplantations, though with a somewhat larger cost savings. Patients who received a second transplant had substantially higher average costs for year  $\geq 0$  (Table 3). Transplant patients who returned to dialysis had significantly higher costs for year  $< 0$  and year  $\geq 0$  compared with patients who had successful transplantations (Table 3). The costs also increased faster in the years  $> 0$  as more and more patients returned to dialysis.

### Health care cost for episodes directly related to dialysis/transplantation

The average cost of the inpatient episode when the transplantation was performed was €34 816. This amount does not include costs for identification of a donor and organ donation. The average cost of an outpatient episode of dialysis averaged €486. With an average of three episodes of HD per week, the yearly cost equalled €75 800. This does not include dialysis during inpatient care, as this would overestimate the cost of dialysis since those episodes generally have other primary activities. Some dialysis-related costs exist in primary care, but they are rare and relatively low and were therefore disregarded.

### Factors associated with health care cost savings

Table 4 shows factors associated with the effectiveness of kidney transplantation, here defined as the cost savings in the

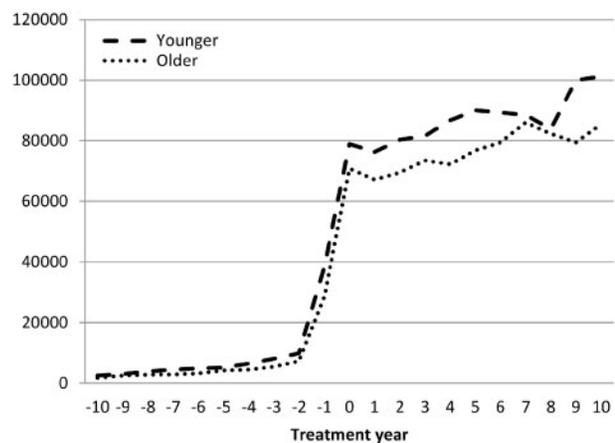


Fig. 2. Health care costs in euros (€) for patients on dialysis, stratified by age. Year 0 = the first year on RRT. Younger [mean age 63 (range 0–74) years] compared with older [mean age 81 (range 74–97) years] patients.

health care sector in the first year after transplantation compared with the year before transplantation. Neither gender nor year of transplantation nor waiting time had an influence on the size of the cost savings. Both requiring an additional transplantation and age were associated with higher costs and therefore with reduced cost savings. However, the age effect was isolated to the younger part (mean split) of the sample, where each additional year of age was estimated to reduce the cost savings by €1084. The overall explanatory power of the model is very low.

### Discussion

Using a before–after design, we found that kidney transplantation rapidly reduced the health care cost per patient. Although the results indicate that the cost savings was reduced over time, the cost was still 75% lower than the expected cost in the absence of transplantation after 6 years and 66% lower after 10 years. This corresponds to a total cost savings of €380 000 (€324 000 discounted) over 10 years for each transplanted patient. The health care costs for dialysis showed an upward trend over time in treatment. This indicates that the assumption that the cost during the year before transplantation would continue in the absence of transplantation is conservative and that the actual cost savings of a kidney transplantation is

Table 3. Health care costs stratified by outcome, up to 10 years before and after kidney transplantation (Tx)

Year <sup>a</sup>	Successful transplantation		Retransplantation		Return to dialysis	
	Observations (n)	Average cost (€)	Observations (n)	Average cost (€)	Observations (n)	Average cost (€)
-10	464	1644	7	621	26	7021**
-9	557	2125	10	2595	35	7398**
-8	630	3116	12	1481	39	5699
-7	698	3584	15	3729	51	6957*
-6	773	5503	19	8574	59	10247*
-5	842	7914	19	9639	70	12640*
-4	902	14456	27	12582	81	22800
-3	954	22379	34	22586	94	28844
-2	993	33906	41	38600	101	43223*
-1	1028	51596	43	47869	106	62868*
0	928	58036	47	94001**	106	88135**
1	814	8474	45	44612**	101	25299**
2	710	6487	42	51927**	95	28931**
3	611	7206	41	43353**	86	25878**
4	521	7353	40	43506**	77	25730**
5	427	6181	37	35975**	64	44139**
6	351	6477	34	38642**	60	32759**
7	279	7177	31	33525**	47	40166**
8	211	6504	25	31337**	41	42529**
9	158	8325	24	31139**	30	50238**
10	100	6864	17	40718**	22	50013**

<sup>a</sup>Year 0 = the year of transplantation. Asterisks indicate significant differences compared with successful transplantation at the \*\*1% and \*5% significance level.

Table 4. Regression results for before–after differences in health care costs in euros (€)

	Full sample	< 49 years	> 49 years
Women	-5120	-5296	-6082
Year of transplantation	509	-824	1137
Age at transplantation	445**	1084***	912
Return to dialysis	16548*	5478	21,397
Retransplantation	52708***	57462***	41241*
Waiting time	-3	-19***	6
Constant	-73814	-72703***	-115890***
N	816	351	465
Adjusted R <sup>2</sup>	0.020	0.112	0.007

OLS regressions with statistical significance at the \*\*\*1%, \*\*5% and \*10% significance level, respectively. A negative figure indicates increased cost savings.

probably higher. Li et al. [3] found in the UK that health care costs for patients on dialysis and transplantation actually fell over time in treatment, as did the probability of incurring costs. However, the cost development of dialysis reported in Li et al. is not an appropriate estimation of the health care costs in the absence of a transplant, as the cost of dialysis maintenance was excluded [3]. Therefore theirs are not comparable with the figures reported in the current study.

The size of the cost savings depends on the outcome of the transplantation, where successful transplantations have the largest cost savings. For patients who receive an additional transplant during the follow-up, the first transplantation is only cost saving after 9 years. This is related to the high cost during the year of and the years after the first transplantation. However, even for patients who return to dialysis, kidney transplantation is cost saving already in the first year after transplantation and remains so for the full 10-year follow-up period.

This is so despite a much higher cost for the year of transplantation compared with successful transplantations. It is interesting to note that patients in our study who returned to dialysis after transplantation had significantly higher health care costs for almost all 10 years prior to the transplantation. The year of transplantation was not associated with the size of the estimated cost savings, indicating that the study period is homogeneous and appropriate for pooling.

No particular differences in health care costs could be found between men and women and between younger and older patients, which generally is in line with the findings reported in Li et al. [3]. There were two exceptions to this: children (<16 years of age) undergoing a kidney transplant had substantially higher costs compared with adults despite a higher rate of living-donor transplantation (79%) and younger patients on dialysis had higher costs compared with older patients. The latter could potentially be explained by the fact that diabetic nephropathy is more common as primary kidney disease among younger patients. It should be noted that only one patient among the younger part of the sample, and none of the children, underwent pancreas transplantation.

The results were confirmed in the OLS regression, where age at transplantation was only significant for the younger part of the sample. Neither gender nor waiting time was significantly associated with cost savings. Indications are that, compared with living-donor transplantation, deceased-donor transplantation is associated with higher costs post-transplantation. This would be expected based on prior research showing better outcomes after living-donor transplantation. However, the difference during follow-up was borderline significant as often as it was borderline insignificant, making it difficult to draw any conclusions. Further studies are therefore needed to establish whether other factors are associated with both transplantation type and health care costs post-transplantation.

Chamberlain et al. [4] estimated the cost for the first 3 years after transplantation in Sweden to be €45 500–70 500. These

figures cannot be directly compared with the results of the current study due to differences in definitions. However, an attempt to adjust our results to achieve greater harmonization with Chamberlain *et al.*, where the cost of the actual transplantation episode was subtracted, would give a 3-year cost of €51 000 in the present study. This is at the lower end of the range estimated in Chamberlain *et al.*, lending some credibility to both figures. Chamberlain *et al.* [4] found, when comparing their figures to other European countries, that the Swedish costs were about twice as high, which would indicate that the estimated costs in this study are not generalizable to other countries. However, the estimated cost savings are similar to prior studies. Reporting from the UK, Li *et al.* [3] found similar cost savings after 6 years as reported in the current study and a likewise rapid decrease in health care costs after kidney transplantation has previously been shown in Finland [10].

In this study, we calculated the average health care costs for each full year after transplantation or start of RRT. This approach runs the risk of excluding some costs related to a patient's death. We therefore also calculated the cost of the last life year for all patients who died during the study period. These costs (~ €85 000) were relatively similar between transplanted patients and patients on dialysis, which implies that the cost increase related to death is higher among transplanted patients. However, this larger cost increase among transplanted patients does not affect the cost-saving feature of transplantation.

### Limitations

The assumption that the costs for the year before transplantation will continue in a scenario without transplantation is conservative, as the cost of dialysis tends to increase over time in treatment. A reduced mortality rate for transplantation compared with dialysis can be expected to continue for up to 25 years after treatment [11]. The current study's follow-up period of 10 years can therefore be seen as a conservative limitation probably underestimating the effect of transplantation compared with dialysis. However, prolonged life also implies health care costs during the additional life years. Another conservative limitation is that 8 days before the transplantation was defined as the start of the transplantation year. This may have overestimated the health care costs, as some costs due to the underlying disease will be attributed to the transplantation year.

One data limitation is the exclusion of private health care providers in one of the two regions under study, Skåne, due to legal restrictions. Analysis of the data from the other region, Stockholm, where both public and private providers were included, shows that this limitation underestimates the costs. However, the underestimation is relatively small and the cost structures of private and public care are similar, indicating that the effect on the analysis and conclusions should be minor.

Finally, the current study does not include all costs related to kidney transplantation. Costs related to identification and care of a presumptive donor and graft retrieval should be included in the total health care costs.

Future research should apply more advanced statistical methods in order to estimate the cost savings of switching a patient on dialysis to transplantation. Together with other future studies on the treatment effects on health and socioeconomic outcomes, this would allow for much needed cost-effectiveness estimates of interventions and would ultimately be hoped to increase donations.

### Conclusion

This study shows that performed kidney transplantations have resulted in substantial cost savings for the Swedish health care system over 10 years following transplantation. An expansion of the research that carefully identifies patients on dialysis with the highest ability to benefit from transplantation is well placed to further reduce the health care costs of RRT. It is hoped that positive medical values along with cost savings in the health care sector may lead to increased engagement for organ donation in intensive care and consequently to more candidates for organ donation being identified.

### Funding

The study was partly funded by the Swedish Department of Social Affairs. Parts of the results in the current article have been published in a Swedish Government Official Report regarding organ donation and transplantation [12]. The funder had no influence over any aspect of the current study.

### Conflicts of interest statement

None declared.

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