Original Article

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Prevalence of hypertension and uncontrolled hypertension after solid organ transplantation: a 5-year follow-up of the Swiss Transplant Cohort Study

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Objective: Hypertension (HTN) increases cardiovascular risk and is a frequent finding across all solid organ transplant recipients. We describe the prevalence of HTN and uncontrolled HTN, as well as details on pharmacologic treatment of HTN across solid organs transplant recipients up to five years after transplantation.

Methods: This retrospective study is nested in the prospective Swiss Transplant Cohort Study (www.stcs.ch) that includes kidney, heart, lung, and liver transplantation. Data extraction from 2008 to 2019 was used for this study and follow-up data at 6, 12 and 60 months was analyzed.

Results: A total of 3865 transplant recipients were included for analysis. The prevalence of HTN at 6 and 60 months was 88.9% and 90.4% in kidney ($P = 0.21$), 61.8% and 76.1% in liver ($P < 0.01$), 72.6% and 84.9% in lung ($P < 0.01$), and 89.3% and 85.8% in heart ($P = 0.33$) transplant recipients, respectively. The prevalence of uncontrolled HTN at 6 and 60 months was 40.3% and 38.9% in kidney ($P = 0.48$), 21.2% and 30.5% in liver ($P = 0.05$), 26.0% and 36.8% in lung ($P = 0.03$) and 38.9% and 18.5% in heart ($P < 0.01$) transplant recipients, respectively. At 12 months, compared to heart transplant recipients, kidney [odds ratio (OR) = 1.6, 95% confidence interval (CI) 1.1–2.1], liver (OR = 1.7, 95% CI 1.1–2.6) and lung (OR = 2.6, 95% CI 1.6–4.0) transplant recipients had a higher likelihood of presenting with uncontrolled HTN.

Conclusion: HTN prevalence after solid organ transplantation is high. Uncontrolled and untreated HTN remain a major issue post transplantation, particularly in organ recipients not necessarily suffering from cardiovascular diseases such as liver or lung transplant recipients.

Keywords: cohort study, hypertension, prospective study, solid organ transplantation

Abbreviations: ABPM, ambulatory BP measurement; ACEI/ARB, angiotensin-converting enzyme inhibitors and angiotensin-II-receptor antagonists; AlphaA, alpha-adrenergic agents (alpha1 antagonists and alpha2 agonists); BB, beta-blockers; BMI, body mass index; BP, blood pressure; CCB, calcium-channel blockers; CKD-EPI, chronic kidney disease – epidemiology collaboration; CNI, calcineurin inhibitors; DIUR, diuretics; GFR, glomerular filtration rate; HTN, hypertension; MMF, mycophenolate mofetil; OR, odds ratio; SOT, solid organ transplantation; STCS, Swiss Transplant Cohort Study

INTRODUCTION

The drastic improvement of graft survival after solid organ transplantation (SOT) means that patients' long-term outcomes are now more associated with cardio-vascular morbidity. Traditional risk factors including hypertension (HTN), diabetes, dyslipidemia, smoking, kidney function and other nontraditional risk factors like rejection episodes and the use of immunosuppressive drugs lead to higher incidence of posttransplantation cardiovascular diseases [1–3]. The latter remain the leading cause of death after SOT and are intimately linked to graft survival [4,5]. Among kidney transplant recipients, 10-year mortality ranges between 25% and 30%, of which 15% is associated with cardiovascular complications [6].

HTN is a frequent finding across all solid organ transplant recipients. Kidney and heart transplant recipients have the highest prevalence of HTN (80–90%) and 50–90% of lung and liver transplant recipients develop HTN in the first year [7–9]. HTN has been associated with graft dysfunction, death-censored graft failure and death [10]. Patient's long-term survival is also related to blood pressure control [11]. Mechanisms contributing to HTN after SOT are closely linked to kidney function, immunosuppression protocols (mainly the use of calcineurin inhibitors (CNI),

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and steroids), new-onset diabetes and weight gain. Some factors are specifically related to the transplanted organ, like renal transplant arterial stenosis or denervation and restrictive hemodynamics in heart transplantation [12–15].

So far, few epidemiological studies have analyzed blood pressure trajectories in the first years following SOT, stratifying according to the transplanted organs. The aim of our study was to describe the prevalence of HTN and provide insight in drug use across the different type of organs recipient. We describe the prevalence of HTN and uncontrolled HTN, as well as details on pharmacologic treatment of HTN across solid organs transplant recipients including kidney, heart, lung, and liver, and up to 5 years after transplantation.

METHODS

Data source

This retrospective study is nested in the prospective Swiss Transplant Cohort Study (STCS, www.stcs.ch). The multicenter cohort study has been described elsewhere [16,17] and includes all Swiss transplant centers (Geneva, Lausanne, Zurich, Bern, Basel, and St. Gallen). Briefly, data on every SOT performed in Switzerland are prospectively collected and stored in the centralized STCS database since 2008 [17]. Data collection takes place at the day of transplantation (baseline) and at each follow-up visit (6 and 12 months, and yearly after) until death or graft loss. The STCS was approved by the Ethic Committees of all participating centers and all included patients gave a written consent. Data extraction from 2008 to 2019 was used for this study. Follow-up data of the first five years post transplantation were analyzed. All patients with kidney, heart, lung, and liver transplantation were included. Multiple transplantations (simultaneous or sequential), pancreas, islets and small bowel transplants were excluded (Figure S1, Supplemental digital Content, http://links.lww.com/HJH/C588).

Clinical data

Patients' characteristics including office blood pressure (BP) data were recorded at baseline (before transplantation) and at 6, 12, 24, 36, 48 and 60 months after SOT. HTN was defined as BP $\geq$140 systolic or 90 mmHg diastolic, or the use of antihypertensive drugs. Treated HTN included all patients on antihypertensive treatment. Controlled HTN was defined as BP $<$ 140 and 90 mmHg while on antihypertensive treatment. Uncontrolled HTN was defined as BP$\geq$140 or 90 mmHg while on antihypertensive medication. Untreated HTN defines patients with BP$\geq$140 or 90 mmHg without treatment. Resistant HTN was defined as failure to lower office blood pressure to $<$140/90 mmHg despite a combination including a thiazide/thiazide-like diuretic, an ACEI/ARB and a CCB in line with the 2023 ESH Guidelines [18]. Stages of hypertension were defined as: stage 1: BP 140–159/90–99 mmHg, stage 2: BP 160–179/100–109 mmHg and stage 3: BP$\geq$180/110 mmHg. Antihypertensive drug classes captured in the STCS were regrouped in angiotensin-converting enzyme inhibitors and angiotensin-II-receptor antagonists (ACEI/ARB); calcium-channel blockers (CCB), beta-blockers (BB); alpha-adrenergic agents ($alpha_1$ antagonists and $alpha_2$ agonists) (AlphaA); diuretics (DIUR) and other antihypertensive drugs (vasodilators).

Body mass index (BMI) categories were defined as normal (BMI $<$ 25 kg/m^2), overweight (BMI 25–29.9 kg/m^2) and obese (BMI $\geq$30 kg/m^2). Glomerular filtration rate (GFR) was estimated by chronic kidney disease – epidemiology collaboration (CKD-EPI) creatinine Eq. (2009) [19], and CKD stages classified according to KDIGO 2012 classification.

Immunosuppression protocols in Switzerland are standardized across centers and according to organs. Patients are given induction and maintenance immunosuppression according to their immunological risk status. Basiliximab is used as induction therapy for all organs in low immunological risk patients, while antithymocyte globulins are used in high immunological risk patients and in the case of delayed graft function. In a very small proportion of kidney transplant recipients, no induction is given (full HLA-matched living donation) or belatacept is used as induction and for maintenance immunosuppression to avoid the use of calcineurin inhibitors (CNI). Maintenance immunosuppressive therapy generally consists of steroids at tapering doses, tacrolimus, and mycophenolate mofetil (MMF) or mTOR inhibitors (particularly in kidney and heart transplantation, aiming at lower tacrolimus trough levels). Tacrolimus has replaced cyclosporin A in the majority of maintenance protocols.

Statistical analysis

All statistical analyses were done by Stata version 16 (Stata Corp., College Station, TX, USA). Results were expressed as mean $\pm$ standard deviation for continuous variables and as number of patients (%) for categorical variables. Bivariate analysis was performed using the χ^2 test and Student's *t*-test for categorical and continuous data, respectively. Independent risk factors associated with HTN identified in bivariate analysis, such as gender, age, BMI, eGFR and transplant type, were used in the logistic regression model to estimate odds ratio (OR) for uncontrolled HTN at 12 and 60 months after SOT. Trends were assessed using multilevel mixed-effects logistic regression using patient's ID in random effects part. All P values were two-tailed and a P value $<$ 0.05 was considered significant.

RESULTS

Characteristics of the patients

A total of 3865 transplant recipients were included for analysis (kidney n = 2287, liver n = 859, lung n = 392 and heart n = 327). Baseline characteristics of SOT recipients are summarized in Table 1. Compared to other organs, lung transplant recipients differed by a higher proportion of women, lower BMI, and absence of active smoking (as required for transplant eligibility). Kidney and liver transplant recipients were older, had higher BMI and more diabetes at the time of transplantation. Although the difference in BMI was statistically significant, it was not considered clinically relevant. The mean baseline blood pressure was the lowest in heart transplant recipients. Estimated GFR was highest in heart transplant recipients and lowest in lung transplant recipients. After 6 months of follow-up, complete

TABLE 1. Baseline characteristics of 3865 adult solid organ transplant recipients

	Kidney $n=2287$	Liver $n=859$	Lung $n=392$	Heart $n=327$	All $n=3865$	*P*-value
Women (%)	826 (36.1)	265 (30.9)	186 (47.5)	81 (24.8)	1358 (35.1)	<0.001
Age (years)	53 ± 14	55 ± 11	50 ± 14	50 ± 13	53 ± 13	<0.001
BMI (kg/m^2)	26.0 ± 5.0	27.0 ± 15.5	22.3 ± 4.7	26.4 ± 18.4	25.9 ± 10.1	<0.001
BMI categories (%)						<0.001
Normal	979 (44.9)	385 (45.4)	271 (69.5)	155 (48.3)	1790 (47.9)	
Overweight	782 (35.8)	278 (32.8)	100 (25.6)	119 (37.1)	1279 (34.2)	
Obese	421 (19.2)	185 (21.8)	19 (4.9)	47 (14.6)	672 (18.0)	
Smoking categories (%)						<0.001
Never	575 (46.1)	144 (34.5)	90 (45.5)	47 (32.4)	856 (42.6)	
Stopped	476 (38.1)	193 (46.2)	108 (54.5)	90 (62.1)	867 (43.2)	
Active	197 (15.8)	80 (19.2)	0 (0)	8 (5.5)	285 (14.2)	
Diabetes (%)	447 (19.6)	199 (23.2)	50 (12.8)	54 (16.5)	750 (19.4)	<0.001
Total cholesterol (mmol/l)	4.4 ± 1.2	3.4 ± 1.7	4.5 ± 1.6	4.3 ± 1.3	4.2 ± 1.4	<0.001
LDL-cholesterol (mmol/l)	2.3 ± 1.0	1.9 ± 1.2	2.5 ± 1.2	2.4 ± 1.0	2.2 ± 1.1	<0.001
SBP (mm Hg)	141 ± 21	124 ± 21	126 ± 19	102 ± 16	133 ± 23	<0.001
DBP (mm Hg)	81 ± 13	71 ± 15	79 ± 13	67 ± 11	78 ± 15	<0.001
Creatinine (μmol/l)	na	103 ± 77	67 ± 21	126 ± 56	99 ± 67	<0.001

BMI, body mass index; DBP, diastolic blood pressure; na, not available; SBP, systolic blood pressure.
Results are expressed as number of patients (column percentage) for categorical variables and as mean with standard deviation for continuous variables. Between-group comparisons were performed using chi-square for categorical variables and analysis of variance for continuous variables.

data on blood pressure was available for 3637 patients and after 5 years for 1559 patients. CKD stages over the 60 months of follow-up after SOT are summarized in Table S1, Supplemental digital Content, http://links.lww.com/HJH/C589.

Prevalence of hypertension

The prevalence of HTN at 6 and 60 months was uncontrolled HTN and untreated HTN at 6 and 60 months are illustrated in Fig. 1. Overall, the prevalence of HTN tended to increase with time in all groups except in heart transplant recipients. The prevalence of HTN at 6 and 60 months was 88.9% and 90.4% in kidney ($P=0.21$), 61.8% and 76.1% in liver ($P<0.01$), 72.6% and 84.9% in lung ($P<0.01$), and 89.3% and 85.8% in heart ($P=0.33$) transplant recipients, respectively. Kidney and heart transplant recipients had the highest prevalence of HTN at 6 months, with nonsignificant change at 60 months. Liver and lung transplant recipients presented a significant rise in prevalence of HTN from 6 to 60 months follow-up. Details on prevalence of HTN over the complete follow-up period (6, 12, 24, 36, 48 and 60 months) and mean blood pressure values are available in Tables S2 and S3, Supplemental digital Content, http://links.lww.com/HJH/C589.

The prevalence of uncontrolled HTN at 6 and 60 months was 40.3% and 38.9% in kidney ($P=0.48$), 21.2% and 30.5% in liver ($P=0.05$), 26.0% and 36.8% in lung ($P=0.03$) and 38.9% and 18.5% in heart ($P<0.01$) transplant recipients, respectively. Liver and lung transplant recipients showed significant increase in uncontrolled HTN over the follow-up period, whereas heart transplant recipients had lower prevalence of uncontrolled HTN at 60 months.

At 6 and 60 months, the prevalence of untreated HTN was 5.4% and 3.9% in kidney ($P=0.09$), 18.2% and 16.8% in liver ($P=0.64$), 23.6% and 12.3% in lung ($P=0.01$) and 7.7% and 8.3% in heart ($P=0.74$) transplant recipients, respectively. Untreated HTN was highest in liver and lung transplant recipients compared to kidney transplant recipients at 6 and 60 months.

The stages of HTN for uncontrolled HTN are summarized in Table S4, Supplemental digital Content, http://links.lww.com/HJH/C589. The majority on uncontrolled HTN was stage 1 HTN with 78.7% in kidney, 66.0% in liver, 59.1% in lung and 67.3% in heart transplantation after 6 months.

Bivariate analysis of the factors associated with controlled and uncontrolled HTN at 12 months after SOT are resumed in Table 2. In this analysis, uncontrolled HTN is

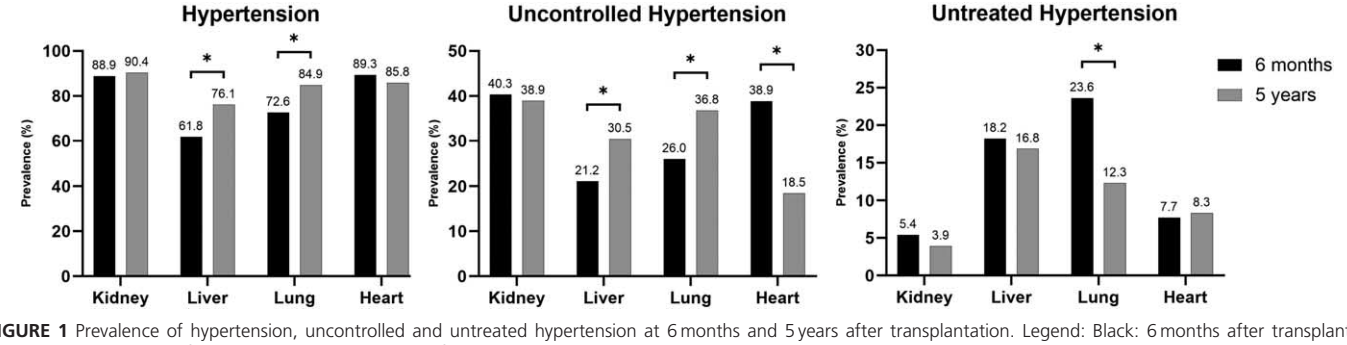

FIGURE 1 Prevalence of hypertension, uncontrolled and untreated hypertension at 6 months and 5 years after transplantation. Legend: Black: 6 months after transplantation; dark grey: 5 years after transplantation. * *P* value of <0.05.

TABLE 2. Bivariate analysis of the factors associated with controlled and uncontrolled hypertension (expressed as a proportion of total treated hypertension) at 12 months after solid organ transplantation

	Controlled $n = 1053$	Uncontrolled $n = 1014$	*P*-value
Women (%)	337 (32.0)	318 (31.4)	0.001
Age (years)	52.7 ± 13.3	56.6 ± 12.0	<0.001
BMI (kg/m^2)	26.6 ± 12.9	26.9 ± 6.9	<0.001
eGFR (ml/min)/1.73m^2	58 ± 24	56 ± 20	<0.001
Transplant type (%)			<0.001
Kidney	763 (72.5)	737 (72.7)	
Heart	115 (10.9)	64 (6.3)	
Liver	111 (10.5)	125 (12.3)	
Lung	64 (6.1)	88 (8.7)	

BMI, body mass index; eGFR, estimated glomerular filtration rate; CKD-EPI, chronic kidney disease – epidemiology collaboration.
Results are expressed as number of patients (column percentage) for categorical variables and as mean with standard deviation for continuous variables. Between-group comparisons were performed using chi-square for categorical variables and analysis of variance for continuous variables.

expressed as a proportion of treated HTN. Uncontrolled HTN was significantly positively associated with male gender, age, BMI and negatively associated with eGFR. Liver and lung transplant recipients had higher percentage of uncontrolled HTN.

Multivariable logistic regression analysis of uncontrolled HTN at 12 and 60 months after SOT are summarized in Table 3. At 12 months, compared to heart transplant recipients, kidney [odds ratio (OR) = 1.6, 95% confidence interval (CI) 1.1–2.1], liver (OR = 1.7, 95% CI 1.1–2.6) and lung (OR = 2.6, 95% CI 1.6–4.0) transplant recipients had a higher likelihood of presenting with uncontrolled HTN. This observation was more pronounced after 5 years of follow up, with an OR of 2.5 (95% CI 1.5–4.4), 4.2 (95% CI 2.2–8.0) and 3.7 (95% CI 1.8–7.6) for kidney, liver, and lung transplant recipients, respectively. The CKD stage was associated with uncontrolled HTN at 60 months of follow-up with an OR of 1.5 (95% CI 1.1–2.0) per CKD stage.

TABLE 3. Multivariable logistic regression analysis of uncontrolled hypertension (expressed as a proportion of total treated hypertension) at 12 months and 5 years after solid organ transplantation

Uncontrolled hypertension	12 months (OR, CI)	5 years (OR, CI)
Transplantation		
Heart	1.00 (reference)	1.00 (reference)
Kidney	**1.59 (1.14-2.21)**	**2.53 (1.47-4.37)**
Liver	**1.72 (1.14-2.59)**	**4.16 (2.17-7.97)**
Lung	**2.55 (1.62-4.03)**	**3.73 (1.83-7.61)**
Gender (male vs. female)	1.02 (0.84-1.24)	1.05 (0.78-1.41)
Age (per year)	**1.02 (1.02-1.03)**	**1.02 (1.01-1.03)**
BMI categories		
Normal	1.00 (reference)	1.00 (reference)
Overweight	1.17 (0.96-1.44)	1.04 (0.76-1.41)
Obese	1.13 (0.89-1.44)	1.13 (0.80-1.59)
CKD Stage (Stage 1-5)	1.17 (0.97-1.42)	**1.50 (1.13-2.00)**

BMI, body mass index; CI, confidence interval; OR, odds ratio.
Bold font for *P*-value <0.05.

Antihypertensive drug treatment

Details about the use of different antihypertensive drug classes are showed in Fig. 2. In kidney transplant recipients there was a high prescription of BB, CCB and ACEI/ARB, with CCB being replaced by ACEI/ARB over 5 years of follow-up. In liver transplant recipients, the most common drug classes were ACEI/ARB, BB and CCB. In lung transplant recipients, BB and ACEI/ARB were the most frequently used antihypertensive classes. In heart transplant recipients, ACEI/ARB and CCB were the predominant drug classes and there was a more frequent use of diuretics compared to other SOT recipients. The total number of BP lowering drugs over the 5-year period are presented in Fig. 3. Kidney and heart transplant recipients needed a higher number of antihypertensive medications. The proportions of transplant recipients receiving more than three antihypertensive drugs are displayed in Figure S2, Supplemental digital Content, http://links.lww.com/HJH/C588. After 5 years, 8.8% of kidney, 0.8% of liver, 0.9% of lung and 7.6% of heart transplant recipients received >3 BP lowering drugs.

DISCUSSION

This national cohort study provides detailed insight in BP trends and management of HTN in SOT recipients. The study confirms high prevalence of HTN as described in other transplant cohorts [20–27]. Although early after transplantation overall prevalence of HTN is lower in liver and lung transplant recipients compared to other organs, prevalence of HTN is still high (>60%) and rises to >75% over 5 years of follow-up. Kidney and heart transplant recipients showed the highest prevalence of HTN (85–90%) and consequently, the overall antihypertensive medication burden was higher. After 5 years of follow-up, 7–8% of kidney and heart transplant recipients were prescribed more than three antihypertensive medications compared to <1% in liver and lung transplant recipients.

Uncontrolled hypertension

Uncontrolled HTN remains a major issue in BP control that affects up to 50% of patients in nontransplanted hypertensive patients [28] but also after SOT. As such, Pisano *et al.* [29] showed a prevalence of uncontrolled HTN of 56% with ambulatory BP measurement (ABPM) and 47% with office BP in renal transplant patients. Van Wagner *et al.* [21] documented that only 16% of 600 liver transplant recipients achieved optimal BP control in the first year after transplantation [20–22]. In the STCS, uncontrolled HTN was comparatively low with 30–39% for kidney, liver, and lung transplant recipients and even lower in heart transplant recipients (18%) after 5 years of follow-up. Independent factors associated with uncontrolled HTN included age and type of organ transplant. Furthermore, a lower eGFR contributed to uncontrolled HTN after 5 years of follow-up, underlining that chronic kidney disease is not limited to kidney transplantation but affects all organ transplantation mainly as a consequence of chronic exposure to CNI-based immunosuppression. The comparatively low proportion of uncontrolled HTN reflects a highly medicalized setting with proactive management of HTN after organ transplantation.

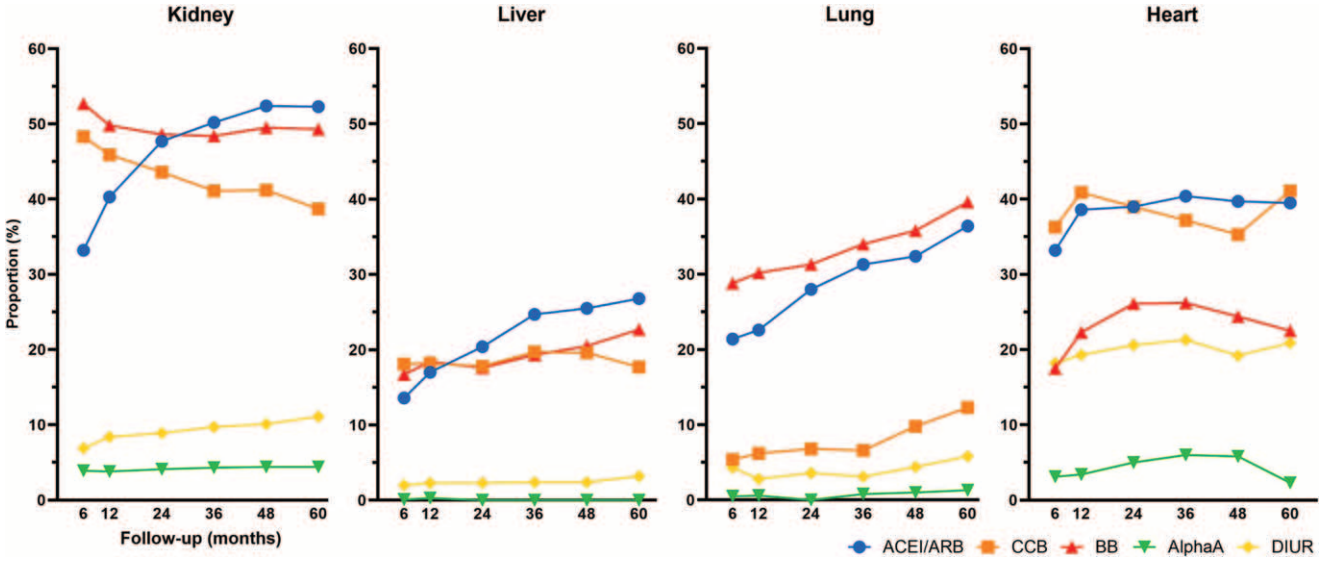

FIGURE 2 Antihypertensive drug class use (% proportion of patients on drug) over a 5-year period after solid organ transplantation. Legend: Blue: ACEI/ARB, angiotensin-converting enzyme inhibitors and angiotensin II-receptor antagonists; orange: CCB, calcium channel blockers; red: BB, betablockers; green: AlphaA, Alpha1 antagonists/Alpha2 agonists; yellow: DIUR, diuretics.

Over 70% of uncontrolled HTN had blood pressure values between 140–159/90–99 mm Hg (stage I). The therapeutic inertia, referring to the reluctance of treating physician to initiate or intensify antihypertensive treatment, is a well known phenomenon, especially in stage 1 HTN. Yet, cardio-vascular outcomes have clearly been linked to better blood pressure control and should encourage a treat-to-target approach even in stage 1 HTN. Also, beyond intensifying antihypertensive treatments, drug adherence should be regularly discussed with the patients.

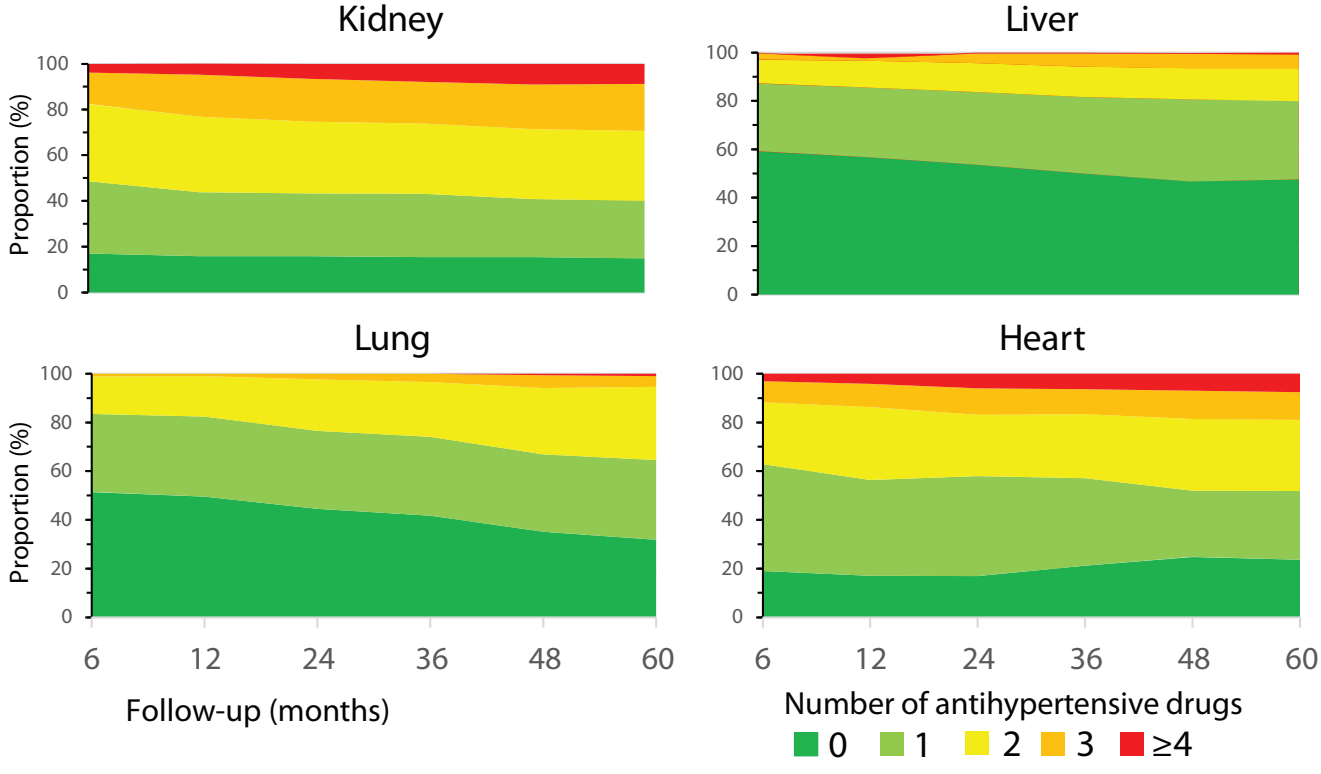

FIGURE 3 Antihypertensive drug burden over a 5-year period after solid organ transplantation. Legend: Number of antihypertensive drugs: dark green: none, light green: 1, yellow: 2, orange: 3, red: >3.

Untreated hypertension

In this cohort, untreated HTN was highest in liver and lung transplant recipients which a prevalence of 20–25%. Especially in liver transplant candidates, prevalence of HTN is low before and steeply increases after transplantation from 15% to 53% as described in Di Stefano *et al.* [24]. The importance of BP control in these high-risk populations should be promoted to encourage proactive BP management.

Furthermore, given the lower BP target recommended in kidney transplant recipients (<130/80 mmHg according to AHA 2017 (IIA) [30] and KDIGO 2021 [31]), the proportion of untreated and uncontrolled HTN among this group is possibly underestimated in kidney transplant recipients.

Antihypertensive drug treatment

This study provides detailed information on treatment schedules longitudinally over a 5-year period after transplantation. We observed great heterogeneity in the use of antihypertensive drug classes across the different transplant groups. Overall, we observed a frequent use of ACEI/ARB across all organs, which increased over time. The same stands for CCB in most organs, except for lung transplant recipients, where the use of BB was predominant.

Among kidney transplant recipients, CCB were progressively replaced by ACEI/ARB over the 5-year follow-up, BB and ACEI/ARB becoming the most frequently used antihypertensive drug classes after 5 years. This is rather surprising, as a Cochrane review and a recent meta-analysis suggested that CCB may be the preferred first line antihypertensive drug, but could be explained by the progressive decline in GFR and the occurrence of albuminuria [32,33]. Furthermore, the low use of diuretics, even in heart transplant patients, should be highlighted and is in line with the general tendency to underuse diuretics for BP management [34].

There is limited data on prescription patterns after SOT. As an example, in kidney transplant recipients, Kuźmiuk-Glembin *et al.* [35] showed a predominant use of BB (about 80%) followed by CCB (about 53%), ACEI/ARB (39%) and diuretics was used in (37%) with an average of 2.5 antihypertensive drugs used. In heart transplant recipients, Nygaard *et al.* showed predominant use of diuretics (43%) and then CCB (26%), BB (23%) and ACEI/ARB (9%) after 1 year of transplantation [36]. Among liver transplant recipients, most patients that received BP lowering drugs received CCB or ACEI/ARB [21].

This heterogenicity in antihypertensive drug prescription illustrates the absence of high-quality evidence and unified guidelines. Many trials, mostly in kidney transplant recipients, failed to reproduce nephroprotective or cardiovascular benefits of certain drug classes, such as ACEI/ARB, contrary to those established in the general population [37]. A recent and large meta-analysis of Pisano *et al.* [33], compared CCB and ACEI/ARB in kidney transplant recipients and concluded that neither ACEI/ARB nor CCB significantly reduced mortality rates, but that CCB and ACEI/ARB reduced the risk of graft loss by roughly 40%. The authors further concluded that insufficient data on the use of BB and diuretics were available.

Strengths and limitations

The strengths of this study include the size of the cohort and the comparison of HTN, across organs after SOT, in a unique comprehensive prospective system of reporting such as the STCS. Characterization of controlled, uncontrolled, and untreated HTN emphasizes the difference in BP control and degree of resistance of HTN between the different organ transplant recipients, as well as prescription habits of treating physicians (nephrologists, cardiologists, pneumologists, gastroenterologists and surgeons). This study enabled detailed insight in antihypertensive drug use, drug burden and prevalence of resistant HTN due to precise information on medication during follow-up after SOT.

Possible limitations of our study concern the focus on mostly European patients that might not allow for general conclusions in other populations. Furthermore, the use of office BP measurement may not detect masked or white coat HTN [29,38]. Masked HTN or white coat HTN, typically diagnosed with ABPM, have been described to be particularly prevalent among kidney transplant recipients with an average prevalence of masked HTN of 26% and white coat HTN of 10% in Pisano *et al.* [29]. Masked HTN is associated with organ damage such as left ventricular hypertrophy [29,39,40]. Based on these observations, prevalence of HTN might even be higher in our cohort, underlining the need of a) accurate screening and b) pro-active treatment approach.

Furthermore, the observational design of this study does not allow for conclusions regarding the optimal antihypertensive treatment or the underlying pathophysiological mechanisms involved in the development of hypertension. The primary focus was to describe the landscape of antihypertensive drug use over time and according to organ type. More interventional outcomes studies are crucially needed in order to guide clinical practice and improve outcomes.

CONCLUSION

In conclusion, HTN prevalence after SOT is high. Uncontrolled and untreated HTN remain a major issue post transplantation, particularly in organ recipients not necessarily suffering from cardiovascular diseases such as liver or lung transplant recipients.

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Availability of data: The anonymized data are available upon reasonable request for a collaborative research project and upon approval by the STCS Scientific committee.

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Conflicts of interest

There are no conflicts of interest.

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