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ORIGINAL ARTICLE

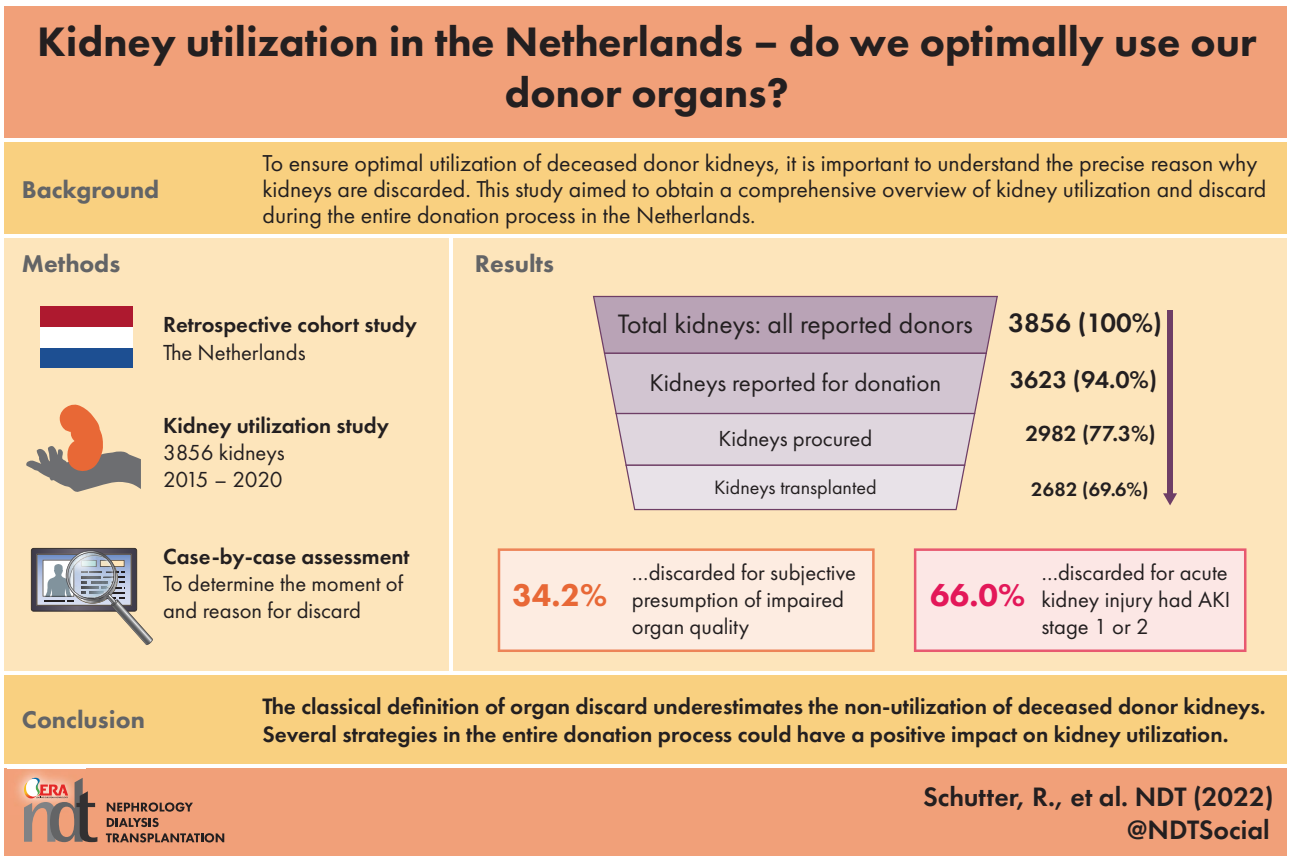
Kidney utilization in the Netherlands—do we optimally use our donor organs?

Rianne Schutter[1], Willemijn A.L. Vrijlandt[1,*], Gelske M. Weima[1,*], Robert A. Pol[1], Jan-Stephan F. Sanders[2], Meindert J. Crop[2], Henri G.D. Leuvenink[1] and Cyril Moers[1]

[1]Department of Surgery – Organ Donation and Transplantation, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands and [2]Department of Nephrology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

*Authors contributed equally.
Correspondence to: Rianne Schutter; E-mail: r.schutter@umcg.nl

GRAPHICAL ABSTRACT



Background. To ensure optimal utilization of deceased donor kidneys, it is important to understand the precise reasons why kidneys are discarded. In this study we aimed to obtain a comprehensive overview of kidney utilization and discard during the entire donation process in the Netherlands.
Methods. In this retrospective cohort study we analysed kidney utilization of 3856 kidneys in the Netherlands between 1

KEY LEARNING POINTS

What is already known about this subject?

- Discard rates of kidneys according to this definition vary, but have been reported internationally to be ≈12–20% in recent years.
- The classical definition of organ discard underestimates the non-utilization of deceased donor kidneys, because non-procured kidneys are ignored.
- It is important to understand the precise reasons why kidneys are not transplanted in order to provide practical solutions for improving kidney utilization.

What this study adds?

- Kidney discard according to the traditional definition (procured but not transplanted) was 7.8%, but once non-procured kidneys are taken into account, total non-utilization was 24.4%.
- Reasons for discard or non-utilization per kidney has been described on a detailed level.
- Two-thirds of kidneys discarded due to acute kidney injury (AKI) had only AKI stage 1 or 2.

What impact this may have on practice or policy?

- Awareness of the numbers of 'unnecessary' discarded kidneys could change the behaviour of donation professionals in the entire donation process.
- Practical suggestions for a future framework in which data on discard and non-utilization will be prospectively collected are provided.

January 2015 and 31 December 2020. For every kidney that was not transplanted, we determined the moment of and reason for discard through a unique case-by-case assessment.

Results. Kidney discard according to the traditional definition (procured but not transplanted) was 7.8%. However, when kidneys that seemed medically suitable at the beginning of the donation process were also included, many more potential donor kidneys were lost and the total non-utilization was 24.4%. Subjectively presumed impaired organ quality was responsible for 34.2% of all discarded kidneys. Two-thirds of kidneys discarded due to acute kidney injury (AKI) had only AKI stage 1 or 2.

Conclusion. The classical definition of organ discard underestimates the non-utilization of deceased donor kidneys. Strategies to improve kidney utilization could be a revision of the maximum allowed agonal time in donation after circulatory death, careful consideration in reporting and accepting kidneys from donors with AKI and a prospectively filled registry of detailed organ discard reasons, including the 'silent' non-utilization before procurement.

Keywords: discard, kidney utilization, organ donation

INTRODUCTION

Given the paucity of deceased donor organs, it is essential to minimize unnecessary organ discard. Clinicians are continuously balancing the risks of accepting or declining marginal organs from suboptimal donors for their individual patients while keeping in mind the long-term effects of their judgment on national waiting lists.

Allocation of kidneys in the Netherlands takes place via the Eurotransplant collaboration network based on international allocation agreements supported by the Eurotransplant Kidney Advisory Committee [1]. In the Netherlands, the decision to accept or decline a kidney is initially made by the on-call nephrologist and subsequently by the transplant surgeon. Allocation of kidneys can take place before, during or after surgical procurement. Preliminary kidney acceptance before retrieval is based on the donor's general medical data, while additional information on the macroscopic aspects during procurement is communicated immediately after removal. Pre-implantation biopsies are not part of the standard procedures and histopathological assessment during procurement is only performed to exclude malignant tissue.

In Eurotransplant, organ discard is defined as the situation in which an organ is procured but not transplanted to a suitable recipient. Discard rates of kidneys according to this definition vary, but have been reported internationally to be ≈12–20% in recent years [2–5]. These discard percentages increase to 60% for kidneys with a high Kidney Donor Profile Index (KDPI), despite findings that transplantation of marginal kidneys provides a survival benefit over dialysis or remaining on the waiting list [6, 7]. Furthermore, the implementation of certain labels [e.g. KDPI, expanded criteria donor (ECD) or Public Health Service 'increased risk' (PHS IR)] has had a paradoxically adverse effect on kidney utilization [7–10].

Specific information on individual reasons for discard is scarce. A recent study investigated the reasons for kidney discard after procurement in France. Vascular abnormalities (43.7%), iatrogenic lesions (26.2%), suspicion of a malignant tumour (18.7%) and severe histological lesions on pre-implantation biopsy (12.3%) were listed as the main grounds [11]. In the USA, elevated kidney discard has been associated with donor age >50 years, biopsy findings, smoking, diabetes, hypertension, creatinine >1.5 mg/dl (133 mmol/L), donation after circulatory death (DCD) and cerebrovascular accident (CVA) as the cause of death [4, 12–14]. Non-procured kidneys in the USA were associated with Black donors, obesity, hypertension, diabetes, hepatitis C, smoking, DCD or CVA as the cause of death. The donors from non-procured kidneys had a lower KDRI compared with donors from procured kidneys, but there was a substantial overlap [15].

To ensure optimal utilization of deceased donor kidneys, it is important to understand the precise reasons why kidneys are not transplanted. The donation procedure starts during a potential donor's treatment at the intensive care unit (ICU) with donor management and covers a complex sequence of events until eventual transplantation. Although the commonly used discard definition only considers events from procurement onward, loss of potential organs can occur anywhere in this cascade.

In this study we aimed to obtain an overview of kidney utilization and discard during the entire donation process in the Netherlands, including 'silent' non-utilization that takes place before procurement. We identified the reasons for non-utilization and discard and from there we discuss options and practical solutions for improving kidney utilization. Our study results derive from a single country, but the insights can also be useful for countries with a similar donation population and allocation system.

MATERIALS AND METHODS

We used data from two different databases on organ donation in the Netherlands from 1 January 2015 to 31 December 2020, all managed by the Dutch Transplantation Foundation and Eurotransplant. Permission for use of these data was obtained from the data management committee of the Dutch Transplantation Foundation and the Dutch organ procurement advisory committee, following the European General Data Protection Regulation and the Dutch Data Protection Act.

Information on potential organ donors at ICUs was obtained through a national registry [Nederlandse Overledenen Registratie Donoren (NORD)] that includes all deceased ICU patients. For this database, all Dutch ICUs are required to report how many patients have died, whether the patient was identified as a potential donor and whether permission for donation was obtained. Only the annual cumulative numbers of (potential) organ donors on a national level were provided for this study.

Another national database [Orgaan Procedure Informatie (OPI)] was used that contains anonymized information on all individual donation procedures with specific information on whether a kidney was reported for donation, procured and transplanted. We divided all (potential) donor kidneys into four different subgroups: kidneys not reported to Eurotransplant for allocation (subgroup A), kidneys reported for allocation but not procured (subgroup B), kidneys procured but not transplanted (subgroup C) and kidneys transplanted (subgroup D). Subgroup B was subdivided into kidneys that were not procured because the donor did not die within 2 h after switching off the ventilator, in case of donation after circulatory death (DCD), and a group of kidneys that was reported but not procured for any other reason.

This extensive database included donor- and kidney-specific information, such as the donor's clinical course in the ICU, blood and urine tests, radiological reports, information on medical history, pathology reports and virology results. Kidney-specific information was available from organ reports formulated by the procuring surgeon, containing details on kidney anatomy, aspect of perfusion, degree of atherosclerosis, morphological abnormalities and general quality assessment of the kidney after procurement. However, this database did not always provide specific information on the reason for discard, but mentioned more general terms such as 'medical problems', 'organizational problems' or 'unknown'. In some cases, the reason for discarding was explicitly described in a free-text box.

For every individual kidney that was not transplanted, we determined the reason for discarding through a case-by-case assessment of all available information in the database. In the majority of cases, we felt that reliable interpretation was possible because comprehensive information on each (potential) donor and each kidney could typically be obtained. For this study, discard reason categories were determined based on the most common discard reasons in a sample of our study population. It should be noted that each categorized reason for discard was based on our best interpretation of all available data and should be considered the presumed reason for discard since no official specific reason was reported in the majority of cases. In several cases, discard was likely to be the result of multiple factors. Kidney discard reason was then labelled according to the presumed most decisive factor through the consensus of a transplantation nephrologist, a transplantation surgeon and a transplant coordinator.

Data were collected in Excel 2010 (Microsoft, Redmond, WA, USA) and further analysis was performed with SPSS 26 (IBM, Armonk, NY, USA). Normal distribution was evaluated with P-P and Q-Q plots and the Kolmogorov–Smirnov test. All non-parametric data are expressed as median and interquartile range (IQR). No statistical analysis was performed, as our cohort does not represent a study sample but comprises the entire donor population from 2015 to 2020.

RESULTS

Donor recognition and permission for donation

Within the time frame of our study, an average of 5% of all deceased people in the Netherlands died in an ICU. Only 12.7% of these patients were potential donors from a medical point of view. Around 74% of all potential donors per year were 'lost' because they were not identified as suitable donors, no permission for donation was obtained or due to several factors that eventually precluded donation during the donation process itself (Fig. 1).

On average, permission for donation (either through consent in the donor registry or by consent from relatives) was obtained in only 36% of all potential donors (350 donors per year). Only 310 were reported to Eurotransplant as actual organ donors. This loss of donors who first seemed medically eligible and for whom permission for donation had been obtained is mainly due to the potential donor's medical history and/or current medical tests revealed medical contraindications for organ donation or presumed insufficient organ quality. Initially given permission for donation by relatives was withdrawn in approximately seven cases per year at this stage of the donation process.

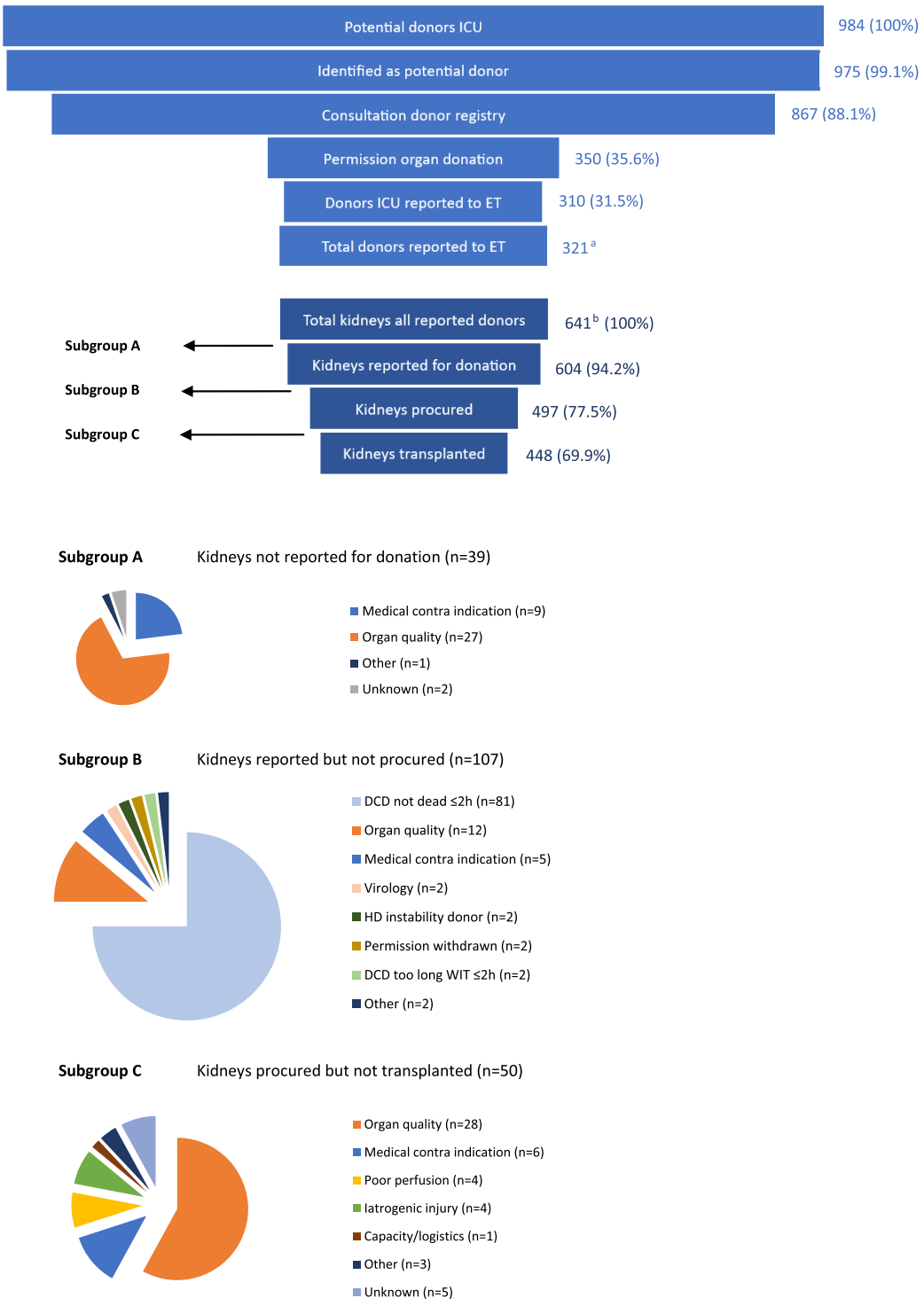


Figure 1: Average annual loss of potential donors and kidneys.
[a]310 reported donors derived from the ICU patient population. On average, 11 patients per year chose to have euthanasia carried out in the hospital to facilitate subsequent organ donation, for a total of 321 reported organ donors per year.
[b]The odd number of kidneys is because donors had a medical history of a previously donated single kidney as a living donor, a unilateral nephrectomy for medical reasons or a congenital single kidney. DCD: donation after circulatory death; ET: Eurotransplant; HD: haemodynamic; WIT: warm ischaemia time.

Table 1: Various definitions of kidney discard and associated percentages.

Discard definition kidney	*n*/*N*	%
Procured but not transplanted (Eurotransplant)	317/3856	8.2
Procured but not transplanted, corrected for procurement for research[a]	300/3856	7.8
Reported for allocation but not transplanted	941/3856	24.4
Reported for allocation but not transplanted (minus DCD not dead <2 h)	457/3856	11.9

[a]Some kidneys are rejected for transplantation before procurement but the relatives give permission to procure the organ for clinical research purposes. As these kidneys are officially counted as procured, they falsely increase the discard rate.

In the Netherlands it is medically and legally possible to donate organs after euthanasia [16, 17], which provides an additional 11 organ donors per year on average. Together with the aforementioned 310 donors identified at the ICU, this adds up to 321 donors per year. In 252 cases at least one successful transplantation was performed. This corresponds with 14.5 organ donors per million inhabitants in the Netherlands, which is relatively low compared with other Western countries such as the UK (18.68), Belgium (21.2), France (23.15), Spain (37.97) and the USA (38.03) [18].

Discard definition

Organ discard numbers are inherently linked to the definition of discard. Eurotransplant utilizes the rather narrow discard definition of 'procured organs that have not been transplanted', leading to an average kidney discard rate of 8.2% between 2015 and 2020 (Table 1). Once corrected for retrieval of kidneys solely for research purposes (that were declined for medical reasons before procurement), the actual discard rate is 7.8%. However, if kidneys are included that seemed medically suitable and were reported for donation, many more potential donor kidneys were lost and the total non-utilization increases to 24.4%.

Kidney utilization and discard

In the 6-year time frame considered, a total of 3856 kidneys were available from the reported donors, of which 30.4% were not used [subgroup A (6.0%) + B (16.7%) + C (7.8%)] and 69.6% were transplanted (subgroup D) (Table 2). We noticed a relatively higher prevalence of DCD and males in discard subgroups B and C compared with the total donor population. Furthermore, discard seemed to be more prevalent when anoxia was the cause of death. Kidneys that were not reported for donation (subgroup A) had a higher incidence of cardiopulmonary resuscitation (CPR) performed in the donor, a longer duration of CPR and a higher prevalence of hypertension and diabetes mellitus compared with the total donor population. In subgroups B and C, donors seemed to have more cardiovascular risk factors in their medical history, such as hypertension, smoking and diabetes mellitus.

We created an annual model, representing the average annual loss of donors and kidneys throughout the different stages of the donation process (Fig. 1). The mean reasons to not report the kidney for allocation (subgroup A) were mainly organ-specific medical contraindications or presumed inferior organ quality. Reasons for discard in subgroup B (besides potential DCD donors that did not pass away within 2 h) were unexpected deterioration of organ quality, later discovered medical contraindications, positive donor virology test results, premature death of the donor, previously granted permission withdrawn by relatives or long warm ischaemia time during the agonal phase of a DCD procedure, after which all potential recipient centres declined the kidney. The classical definition of discard (subgroup C) was mainly because of the presumed inferior quality of the organ. Discard related to iatrogenic injury during organ retrieval was relatively rare, accounting for 0.8% of all procured kidneys. Mild iatrogenic injury that did not lead to actual organ discard was reported more often.

A summary of reasons for discard and non-utilization during the entire donation process is presented in Table 3. Organ quality is a very subjective concept for which no clear cut-off values exist that distinguish a suitable from an unsuitable kidney for transplantation. On an annual basis, a total of 65 kidneys were discarded or not reported because of presumed insufficient organ quality (Table 4). Most of these (potential) kidney donors had impaired renal function, mainly due to acute kidney injury (AKI) acquired during their hospital stay. Approximately 24 kidneys were discarded annually because of AKI, of which two-thirds had only stage 1 or 2 (Table 5). Other causes of 'impaired organ quality' were inadequate visual quality evaluation because adherent perirenal fat could not be removed, atypical vascular anatomy or when the original data mentioned discard because of 'organ quality'.

On average, 20 kidneys per year were not reported or discarded because of a donor- or organ-specific medical contraindication, such as end-stage renal failure, a horseshoe kidney or severe polycystic kidney disease (Table 6). In several cases, both kidneys were discarded because of suspected malignancy elsewhere in the body before organ procurement, even though pathology results in a frozen section during retrieval showed no malignant tissue at all. One of the discard reasons in the original data stated 'medical history turned out to be unacceptable'. Unfortunately, no further details were available and we therefore classified the discard reason of these kidneys as 'medical contraindication'.

Discard reasons that were classified as 'other' included no consent for kidney donation (but permission for other organs), necrotizing intestines discovered during organ procurement, immunological reasons, recipient-related problems with consequently an unacceptably long cold ischaemia time (CIT). In one remarkable case, the donor had received a post-mortem kidney transplantation in the past that was still functioning optimally and could have been procured and retransplanted, but no recipients were found for this allograft.

Table 2: Kidney utilization and moment of discard (2015–2020).

Characteristics	Total kidneys from all reported donors (2015–2020)	'Silent' non-utilization			Official discard	Transplanted
		Subgroup A: kidney not reported for donation	Subgroup B: kidney reported but not procured		Subgroup C: kidney procured, but not transplanted	Subgroup D: kidney transplanted
			DCD not dead <2 h	Other reasons		
Total kidneys, *n* (%)	3856 (100)	233 (6.0)	484 (12.6)	157 (4.1)	300 (7.8)[a]	2682 (69.6)
Sex, *n* (%)						
Male	2119 (55.0)	153 (65.7)	253 (52.3)	107 (68.2)	192 (64.0)	14 174 (52.7)
Female	1737 (45.0)	80 (34.3)	231 (47.7)	50 (31.8)	108 (36.0)	1268 (47.3)
Donation type, *n* (%)						
DBD	1409 (36.5)	116 (49.8)	NA	43 (27.4)	88 (29.3)	1162 (43.3)
DCD	2447 (63.5)	117 (50.2)	484 (100)	114 (72.6)	212 (70.7)	1520 (56.7)
Ischaemia–reperfusion injury						
CPR performed[b], *n* (%)	1357 (35.2)	108 (46.4)	196 (40.5)	61 (38.9)	92 (30.7)	900 (33.6)
Duration of CPR (min), median (IQR)	15 (8–20)	20 (10–30)	14 (6–20)	15 (9–22)	15 (8–26)	15 (8–20)
Age (years), *n* (%)						
0–49	1190 (30.9)	67 (28.8)	100 (20.7)	35 (22.3)	43 (14.3)	945 (35.2)
50–64	1566 (40.6)	83 (35.6)	213 (44.0)	53 (33.8)	125 (41.7)	1092 (40.7)
≥65	1100 (28.5)	83 (35.6)	171 (35.3)	69 (43.9)	132 (44.0)	645 (24.0)
Median (IQR)	57 (47–66)	58 (49–69)	61 (52–67)	62 (52–69)	63 (54–69)	54 (44–64)
Cause of death, *n* (%)						
CVA	1701 (44.1)	97 (41.6)	180 (37.2)	59 (37.6)	124 (41.3)	1241 (46.3)
Anoxia	1086 (28.2)	98 (42.1)	192 (39.7)	59 (37.6)	99 (33.0)	638 (23.8)
Trauma	856 (22.2)	30 (12.9)	98 (20.2)	35 (22.3)	68 (22.7)	625 (23.3)
Other	213 (5.5)	8 (3.4)	14 (2.9)	4 (2.5)	9 (3.0)	178 (6.6)
Presence of comorbidities[b], *n* (%)						
Hypertension	1059 (27.5)	86 (36.9)	149 (30.8)	47 (29.9)	126 (42.0)	652 (24.3)
Smoking	2232 (57.9)	127 (54.5)	302 (62.4)	111 (70.7)	222 (74.0)	1470 (54.8)
Diabetes mellitus	288 (7.4)	33 (14.2)	44 (9.1)	16 (10.2)	46 (15.3)	148 (5.5)
Malignancy	147 (3.8)	11 (4.7)	16 (3.3)	7 (4.5)	13 (4.3)	100 (3.7)
Renal function, median (IQR)						
Last creatinine (μmol/L)	66 (53–86)	158 (95–275)	59 (48–70)	80 (65–132)	72 (54–91)	65 (52–82)
Last eGFR (ml/min/1.73 m^2)	97 (78–109)	36 (19–65)	101 (92–110)	81 (51–99)	92 (73–102)	99 (83–111)

[a]Kidneys that have been declined before procurement but were retrieved for research purposes ($n = 17$) have been included in subgroup A or B, depending on their moment of discard. The actual number of kidneys that were procured is 317.
[b]Marked as 'yes' in medical status, not corrected for 'unknown' status.
CVA: cerebrovascular accident; DCD: donation after circulatory death; DBD: donation after brain death; eGFR: estimated glomerular filtration rate.

Table 3: Reasons for kidney discard or not reporting a kidney for donation.

Reason for discard	Total 2015–2020 ($n = 1174$), *n* (%)	On average per year ($n = 196$), *n*
Potential DCD donor not dead <2 h after withdrawal of ICU treatment	484 (41.2)	81
Organ quality	402 (34.2)	67
Medical contraindication	118 (10.1)	20
Poor perfusion	26 (2.2)	4
Iatrogenic injury	22 (1.9)	4
DCD, too long WIT	14 (1.2)	2
Virology	14 (1.2)	2
Hemodynamic instable donor	10 (0.9)	2
Permission withdrawn	10 (0.9)	2
Capacity/logistics	9 (0.8)	2
Other	28 (2.4)	5
Unknown	37 (3.2)	6

DCD: donation after circulatory death; ICU: intensive care unit; WIT: warm ischaemia time.

Table 4: Specification of kidney discard due to insufficient organ quality.

Reason for discard	Total 2015–2020 ($n = 402$), *n*	On average per year ($n = 67$), *n*
Impaired renal function[a]	175 (141 AKI)	29 (24 AKI)
Structural abnormalities (kidney size, cysts, fibrosis)	46	8
Severe atherosclerosis	51	9
Age + comorbidities	34	6
Proteinuria >1 g/L (with normal eGFR)	26	4
Vascular damage/dissection artery	20	3
Emboli/thrombi/infarction	15	3
Traumatic lesions donor	7	1
Other	23	4
Unknown	5	1

[a]Serum creatinine >100 mmol/L (1.13 mg/dl) and/or eGFR <40 ml/min/1.73 m^2 and/or renal replacement therapy in the ICU.

Table 5: Specification of kidney discard when donor had AKI.

Reason for discard	All discarded AKI kidneys (2015–2020)	AKI stage 1	AKI stage 2	AKI stage 3
Total, *N*	141 (24 per year)	51	42	48
Kidney not reported for donation, *n*	106 (18 per year)	34	32	40
Reported but discarded before procurement, *n*	24 (4 per year)	14	5	5
Discarded after procurement, *n*	11 (2 per year)	3	5	3
Donor age (years), median (IQR)	53 (44–63)	62 (47–69)	56 (47–61)	49 (39–55)
Expanded criteria donor, *n*	66	29	23	14
Standard criteria donor, *n*	75	22	19	34
CPR, *n* (%)	104 (74)	39 (76)	29 (69)	36 (75)
CPR duration (min), median (IQR)	20 (15–45)	20 (15–25)	34 (18–56)	30 (20–45)
Serum creatinine on hospital admission (μmol/L), median (IQR)	107 (84–130)	117 (105–137)	101 (77–120)	106 (79–148)
Highest serum creatinine (μmol/L), median (IQR)	247 (180–340)	181 (143–250)	222 (194–313)	368 (284–472)
Last serum creatinine (μmol/L)[a], median (IQR)	220 (157–323)	174 (142–242)	213 (171–278)	304 (211–418)
Last eGFR (ml/min/1.73 m^2), median (IQR)	25 (19–37)	33 (23–41)	25 (19–34)	19 (14–29)

[a]Censored for patients on renal replacement therapy.

AKI stage 1: serum creatinine 1.5–1.9 times baseline or ≥26.5 mmol/l (≥0.3 mg/dl) increase. AKI stage 2: serum creatinine 2.0–2.9 times baseline. AKI stage 3: serum creatinine 3.0 times baseline or an increase in serum creatinine to ≥353.6 mmol/l (≥4.0 mg/dl) or the need for renal replacement therapy. Urine output in the last 6–24 h was not well documented and was therefore no indicator of the AKI stage in our study.

CPR: cardiopulmonary resuscitation.

Expanded criteria donor: donor >60 years of age or a donor >50 years of age with two of the following: a history of hypertension, creatinine ≥133 μmol/L (1.5 mg/dl) or death resulting from a cerebrovascular accident.

Table 6: Specification of kidney discard due to medical contraindications.

Reason for discard	Kidneys discarded from 2015–2020, *n*	Kidneys discarded on average per year, *n*
Absolute contraindications	38	6
Unknown identity	0	
Active viral infection (rabies, herpes zoster, rubella)	0	
Active tuberculosis	0	
Untreated sepsis	2	
Primary kidney disease	36	6
Relative contraindications	78	13
Age	21	4
Confirmed malignancy during donation	14	2
Suspected malignancy during donation	32	5
Medical history unacceptable	11	2

DISCUSSION

Our study investigated the moments and decisions regarding kidney discard in deceased donor organ donation, including the almost invisible 'silent' non-utilization that takes place before procurement. When this is taken into account, the actual loss of donor kidneys in the Netherlands is ≈24%. Surely, part of this loss can be classified as justifiable discard. But the numbers and associated reasons for kidney non-utilization we found in this study suggest that there is room for improvement.

One of the complicating factors influencing 'traditional' discard rates after procurement is the differing time overlap of kidney allocation and organ procurement. Consequently, some donation procedures of suboptimal donors are cancelled since no recipients were found before procurement, whereas in other cases organs are procured and subsequently counted as discarded organs. Earlier allocation of kidneys (when logistically feasible) could therefore avoid unnecessary retrieval and thus prevent transplant professionals, the donor and next-of-kin from being unnecessarily burdened.

Around 20% of all potential DCD kidneys were never retrieved because the donor's agonal phase exceeded the 2-h national upper limit set for kidney donation. A Canadian retrospective study showed that 21% of potential DCD donors who did not end up donating due to an agonal phase >2 h did sustain cardiocirculatory arrest between 2 and 4 h after withdrawal of treatment [19]. The acceptable maximum duration of the agonal phase is still under debate, but several studies support a waiting time of up to 4 h for DCD kidney donation. As long as the number and duration of hypotensive episodes are limited, acceptable transplant outcomes are reported [19–22]. The duration of the agonal phase is associated with delayed graft function (DGF) but not with long-term graft function [23]. However, a prolonged agonal time in association with a long CIT is associated with an increase in DGF and primary non-function [24, 25]. Implementing the use of kidneys with an agonal time >2 h might initially be limited to national use only to avoid exceeding CIT in 'favourable' standard criteria donors.

The renal transplant community might need more reliable and objective quality assessment tools. Novel pre-transplant *ex vivo* quality assessment via biomarkers or perfusion parameters may provide new insights. *Ex vivo* normothermic machine perfusion (NMP) has the potential to assess kidney

graft viability or even repair marginal kidney grafts [26–28]. In a recent UK trial, DCD kidneys that were declined because they appeared poorly perfused after procurement underwent NMP and were graded on several quality assessment variables, after which some kidneys with favourable scores were successfully transplanted [29]. Kidneys with seemingly poor perfusion from our study cohort might have benefited from a similar assessment. Also, kidneys procured after an agonal time >2 h may benefit from pre-transplantation machine perfusion quality assessment. Further development and implementation of NMP-associated quality assessment could contribute to a future reduction in the number of discarded kidneys.

AKI is a common finding in (potential) deceased donors and is associated with delayed graft function. DGF is less common in recipients with kidneys of non-AKI donors (6.1–28%) compared with kidneys suffering from AKI (23–74%), with DGF rates increasing among AKI stage 3 kidneys or in ECDs [30–34]. Several studies have found higher kidney discard rates when the donor had AKI [30, 35]. Nevertheless, many single and multicentre studies have consistently reported equivalent transplant outcomes in terms of 1-year graft survival and up to 15 years of long-term graft survival compared with non-AKI donors [30–41]. Renal function was also found to be equivalent in several studies, with the longest known follow-up of 10 years (death-censored) showing a non-significant difference in estimated glomerular filtration rate (eGFR) of 58.0 (AKI) versus 60.8 ml/min/1.73 m^2 (non-AKI) [30, 34, 38].

In our analysis of discarded kidneys from donors with AKI, it was remarkable that the majority of these potential kidneys were never even reported for allocation. Although they remain off the radar according to the common definition of kidney discard, non-utilization of these organs could be considered a loss of potential kidneys. There seems to be room for improvement in organ acceptance, especially among standard criteria donors with AKI stage 1 or 2. Caution is advised when kidneys show signs of significant cortical necrosis in ECDs and AKI stage 3. It should be noted, however, that the severity of AKI in our study may be underestimated, due to the relatively high baseline serum creatinine levels upon ICU admission. As a result, the AKI stage threshold, which is calculated by a multiplication of the baseline creatinine level, could be artificially elevated. Stricter guidelines and better reporting functions (e.g. the ability to tick a box whether or not the donor suffers from AKI, including the associated AKI stage, or the recommendation to always request a reliable baseline serum creatinine from a possible consultation before admission) may help in the potential acceptance of kidneys with mild to moderate AKI.

Severe atherosclerosis of the renal artery was the presumed decisive factor of discard in several kidneys, even though the kidney itself appeared to be of adequate quality. A recent large retrospective analysis of Dutch data showed that the macroscopic atherosclerosis score was a strong independent predictor for discard, even when corrected for potential donor- and organ-related confounders. However, atherosclerosis in the grafts was not significantly associated with delayed graft function, 1-year eGFR or long-term graft survival [42]. These results underpin the inaccuracy of subjective organ quality scoring, which should be interpreted with caution.

The most important limitation of our study lies in the retrospective nature, which entails an inevitable risk of information bias, due to the inability to accurately control and complete data collection. Due to often incomplete documentation of the exact discard reasons, we had to reach a consensus and decide on the presumed reason for discard when no clear justification for discard was reported in the original data. We fully endorse the reality that reasons for organ discard are often multifactorial and we believe that our results should be interpreted in this light. Empty fields in medical donor charts could lead to an underestimation of comorbidities. We strongly recommend a framework in which data on discard and non-utilization are prospectively collected, preferably by a central expert officer to avoid interrater variability.

Another limitation of this study is that we could not obtain any data on potential donor recognition at emergency departments. Figures on the estimated loss of potential donors in departments other than ICUs remain unknown. Furthermore, we made no distinction on which day of the week a kidney was rejected. This variable might have affected organ utilization, as weekend discards in the USA turned out to be significantly higher than weekday discards [43].

Comparing donor and kidney utilization between different countries could be interesting, but many relevant differences exist between the national donation programs, and discard rates should always be placed in the context of the kidney exchange program and national legislation. The Netherlands has a relatively high percentage (21.3%) of non-used donors organs compared with other countries in the Eurotransplant network (Austria 10.7%, Belgium 9.7%, Germany 5.9%), but this seems inevitably associated with the substantial DCD donor population (55.9%), even compared with countries with a similar DCD program (Belgium 32.5%, Austria 5.4%) [44] (Supplementary Table 2). Among the participating countries in the Eurotransplant network, 3.7–19.0% of the kidneys were never reported for donation [44], implying a stricter policy for a kidney subjected to the allocation process. Hence this also affects the traditional discard numbers after procurement, which once again emphasizes the complexity of comparing organ discard rates between countries.

This study's findings may help to explore strategies to improve donor kidney utilization. First, it would be desirable to keep track of all potential organ donors in every department in hospitals, to allow a better evaluation of the effectiveness of potential donor identification. Second, it seems worth investigating whether the maximum allowed agonal time of DCD donors can be extended to 4 hour in certain conditions. Third, decision making on the acceptance of suboptimal organs deserves careful consideration based on up-to-date research regarding, for example, the relevance of donor AKI, renal artery atherosclerosis, hepatitis B or C, (suspected) malignancy in the donor and the risk of transmission. Fourth, upcoming new technologies such as pre-transplant warm machine perfusion could provide a platform for a more robust quality assessment of marginal donor kidneys. Last but not least, a prospectively filled and well-maintained registry of detailed organ discard reasons

could be very helpful in studying discard after procurement, as well as non-utilization before procurement. Standardized, but more detailed and organ-specific reasons for discard should be formulated by transplant experts. In case organ discard has multifactorial reasons, the database should allow simultaneous documentation of such factors. This could provide unique insights into organ discard trends, allow critical assessment of whether each kidney was discarded for a justifiable reason, identify specific areas of improvement and serve as the perfect stepping stone for targeted plans for optimizing organ use.

SUPPLEMENTARY DATA

Supplementary data are available at *ndt* online.

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ETHICS STATEMENT

According to Dutch law, permission from an ethics review-committee is not required when a study involves human subjects who are deceased. Dutch law on organ donation states that people who give permission for organ donation automatically also provide consent for transplantation-related research.

AUTHORS' CONTRIBUTIONS

R.S. was responsible for the research design, the acquisition, analysis and interpretation of data and writing the manuscript. W.A.L.V. and G.M.W. were responsible for the acquisition and analysis of data and critical revision of the manuscript. R.A.P. and H.G.D.L. were responsible for critical revision of the manuscript. J.S.F.S. and M.J.C. were responsible for the interpretation of data and critical revision of the manuscript. C.M. was responsible for analysis and interpretation of data and critical revision of the manuscript.

DATA AVAILABILITY STATEMENT

The data are not openly stored, but access is available upon request to the corresponding author.

CONFLICT OF INTEREST STATEMENT

All authors declare no conflicts of interest. The results presented in this article have not been published previously in whole or part.

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