



ORIGINAL ARTICLE

Impact of a phone app on nephrology referral

Nestor Oliva-Damaso¹, Elena Oliva-Damaso², Francisco Rivas-Ruiz^{3,4},
Francisca Lopez¹, Maria Del Mar Castilla¹, Eduardo Baamonde-Laborda²,
Jose Carlos Rodriguez-Perez² and Juan Payan¹

¹Department of Medicine, Division of Nephrology, Hospital Costa del Sol, Marbella, Malaga, Spain,

²Department of Medicine, Division of Nephrology, Hospital Doctor Negrin, Las Palmas de Gran Canaria, Spain,

³Department of Research Unit, Hospital Costa del Sol, Malaga, Spain and ⁴Research Network in Health Services in Chronic Diseases (REDISSEC), Madrid, Spain

Correspondence and offprint requests to: Nestor Oliva-Damaso; E-mail: nestorod@hotmail.com

ABSTRACT

Background. Various factors can lead to inadequate nephrology referral decisions being taken by clinicians, but a major cause is unawareness of guidelines, recommendations and indications, or of appropriate timing. Today, tools such as smartphone applications (Apps) can make this knowledge more accessible to non-nephrologist clinicians. Our study aim is to determine the effectiveness of a purpose-built app in this respect.

Methods. In a retrospective study, nephrology referrals were compared before and after the introduction of the app in clinical practice. The initial study population consisted of first visits by patients referred to our department in 2015, before the introduction of the app. In 2016, the smartphone app NefroConsultor began to be implemented in our hospital. We compared the initial study population with the results obtained for patients referred in 2017, when the app was in use, taking into account clinical features considered, such as urinalysis, proteinuria or kidney ultrasound, to determine whether these patients met currently recommended criteria for referral.

Results. The total study population consisted of 628 patients, of whom 333 were examined before the introduction of the app (in 2015) and 295 when it was in use (in 2017). Among the first group, 132 (39.6%) met established KDIGO criteria for nephrology referral and were considered to be correctly referred. Among the second group, 200 (67.8%) met the criteria and were considered to be properly referred ($P = 0.001$). The increase in the rate of intervention success (before–after app) was 28.8% with a binomial effect size display (Cohen's d effect size) of 0.751. Before the introduction of the app, data for albuminuria were included in 62.5% of nephrology referrals; in 2017, the corresponding value was 87.5% ($P = 0.001$). In the same line, referrals including urinalysis rose from 68.5% to 85.8% ($P = 0.001$). Multivariate regression analysis, using referrals meeting KDIGO criteria as the dependent variable and adjusting for age, sex and referring department, showed that the 2017 group (after the introduction of NefroConsultor) was associated with an odds ratio of 3.57 (95% confidence interval 2.52–5.05) for correct referrals, compared with the 2015 group ($P = 0.001$). References to proteinuria as the reason for nephrology referral also increased from 23.7% to 34.2% ($P = 0.004$).

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Conclusions. Use of the app is associated with more frequent studies of albuminuria at the time of referral and a greater likelihood of proteinuria being cited as the reason for referral. The smartphone app considered can improve the accessibility of information concerning nephrology referrals and related studies.

Keywords: albuminuria, chronic kidney disease, chronic renal failure, chronic renal insufficiency, nephrology referral

INTRODUCTION

Chronic kidney disease (CKD) is a worldwide public health problem with a very high prevalence. Early stages of CKD and end-stage renal disease are both associated with high cardiovascular morbidity, premature mortality and increased health care utilization [1, 2]. The risk of hospitalization and cardiovascular events in patients with CKD progressively increases as the estimated glomerular filtration rate (eGFR) declines [3]. Nephrology referral is generally indicated when there is a rapid decrease in the eGFR, an elevated urine albumin-to-creatinine ratio (ACR) (>300 mg/g) or when urinary red blood cell casts are observed (among other indications) [4]. It is generally held that patients with CKD should be referred to a nephrologist when the eGFR is <30 mL/min/1.73 m², but there is less consensus about referral for patients with higher eGFR, despite the fact that early nephrology referral has been associated with lower treatment costs and decreased mortality [5–12].

This study is based on long experience, together with other medical divisions, of indications for nephrology referral and the issues involved. The clinical situation or features in which nephrology referral is indicated are summarized in the criteria and guidelines published by the Spanish Society of Nephrology [13], which in turn are based on the KDIGO guidelines [4]. Clinicians' knowledge of these guidelines is of great importance in their decisions regarding nephrology referral [14]. NefroConsultor is a smartphone application (app) that indicates whether a patient should be referred to nephrology services, in terms of meeting criteria such as eGFR <30 mL/min/1.73 m² or presenting an elevated urine ACR (>300 mg/g). Instruments such as this app can make knowledge more accessible to non-nephrologist clinicians, but unfortunately their implementation in this field remains limited, and little impact has yet been made on health outcomes [15].

In summary, the present study compares nephrology referrals before and after the introduction of a purpose-built smartphone app that helps clinicians reach a decision in this respect, evaluating the impact of this app by taking into account current guidelines and criteria. We hypothesize that the use of such an app in healthcare can encourage the performance of basic studies like albuminuria analysis before the first evaluation by the nephrologist.

MATERIALS AND METHODS

This retrospective study compares nephrology referrals before and after the introduction of a purpose-built smartphone app for use in clinical practice at the Costa del Sol Hospital (Marbella, Spain). The patients included were referred to nephrology services in the periods January–December 2015 (pre-app group) versus January–December 2017 (app group). Patients were recruited into the study during medical evaluation if they met the following inclusion criteria: (i) first visit to nephrology consultation excluding follow-up visits; (ii) subsequent attendance at the nephrology service; and (iii) aged at least 18 years. In 2016, background and training lectures were given to

clinicians to raise awareness and encourage the use of the app. Specifically, a 30-min lecture was given in January, and then repeated in April, July and October. The lectures were attended by a total of 98 clinicians from the following hospital departments: Internal Medicine, Urology, Cardiology, Haematology, Digestive Medicine, General Surgery and Traumatology, Oncology and Pneumology. This relatively small number of participants enabled us to monitor and ensure attendance. If a clinician was unable to be present at any given lecture, then he/she was invited to attend on the next occasion and thus by the end of 2016, all clinicians in this hospital who referred patients to the nephrology service had been instructed in the use of the app. The app was also publicized in the hospital's internal news service and by other colleagues. At the training lectures, the clinicians were requested to use the app when considering referring a patient to the nephrologist service. They were told that even if the patients did not seem to meet the criteria, they should normally be referred although common sense should prevail. The number of downloads of the app was also recorded. On 1 January 2016, fewer than 500 downloads had been made, but by 1 January 2017, there were over 10 000 according to the Google Play statistics for Spain.

The NefroConsultor app, designed for mobile devices and available in the App Store (for Apple) and Google Play (for Android machines) (available here: <http://www.senefro.org/modules.php?name=apps&op=detalle&id=6>), is based on Spanish Society of Nephrology criteria for nephrology referrals [13]. These criteria in turn are based on those of the KDIGO [4]. The app allows the physician to introduce clinical features such as age, gender, serum creatinine, urine ACR, race and 'other reasons', and then reports whether the patient in question meets the criteria for referral. The app is endorsed by the Spanish Society of Nephrology. Patients are considered to be correctly referred when any of the following criteria are met: eGFR <30 mL/min/1.73 m² or a consistent finding of albuminuria (ACR >300 mg/g); or among 'other reasons', if the patient presents an abrupt or progressive deterioration of kidney function, if there is resistant hypertension and CKD, if there are non-urological urinary red blood cell casts, if there are serum potassium persistent abnormalities, if CKD-associated anaemia is observed, if hereditary CKD or polycystic kidney disease is suspected or if there is recurrent/extensive nephrolithiasis. NefroConsultor was designed to coincide with the referral criteria published by the Spanish Society of Nephrology and KDIGO guidelines [4, 13] and, according to the data introduced, it provides a visual display recommending referral or non-referral (Figure 2A–C). This study compared the referrals made in 2015 (before the app came into use) with those made in 2017. In total, 628 patients were referred from the different hospital departments (Internal Medicine, Urology, Cardiology and others such as Haematology, Digestive Medicine, General Surgery and Traumatology, Oncology and Pneumology). In our healthcare system, general practitioners do not refer patients to the hospital. The fact that all patients were referred from within the same hospital ensured that all the doctors involved had attended at least one of the training lectures. The following

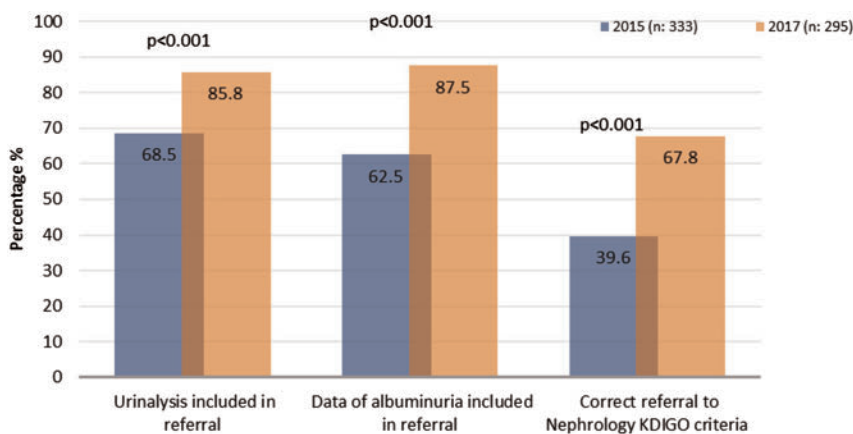


FIGURE 1: Comparison of percentage of patients before and after the use of the app, taking into account urinalysis and albuminuria at time of referral and the correct referral to nephrology service (if current KDIGO criteria are met).

variables were studied: age, sex, serum creatinine and eGFR, number of patients with active urinalysis, level of albuminuria, reason for referral, blood pressure and originating hospital department. If the referral included urinalysis, then the ACR and kidney ultrasound results were also studied.

A descriptive statistical analysis was conducted using measures of central tendency, dispersion and position for quantitative variables and frequency distribution for qualitative ones. Bivariate analysis was performed taking as the segmentation variables the year of evaluation and the appropriateness of the referral made, using the Chi-square test for categorical variables and the Student's t-test (or the Mann-Whitney U-test if the data were not normally distributed) for continuous variables. The effect size of the intervention was assessed according to the binomial effect size display and Cohen's *d* for three referral tests (ultrasound, urinalysis and albuminuria) and for the appropriateness of the referral. Finally, a multivariate logistic regression model was constructed to evaluate the presence of referral appropriateness according to the year of evaluation, adjusting for age, sex and referral provenance, describing the odds ratio with 95% confidence intervals for the year of intervention (2017). In each of these analyses, the level of statistical significance was established at $P < 0.05$. The study was approved by the ethics committee of the Costa del Sol Hospital. However, in view of the low ethical burden, and because the study was based on an analysis of clinical practice, it was exempted from the requirement for signed informed consent.

RESULTS

The study population was composed of 628 patients, with a mean age of 68.1 years, of whom 62.7% were male. The mean serum creatinine level at referral was 1.59 mg/dL and the eGFR was 46.9 mL/min/1.73 m² [Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI)]. The following departments of origin made the largest numbers of referrals: Internal Medicine (283 patients), Urology (139) and Cardiology (38) adding 16 of unknown provenance. The remaining 152 patients were referred from the Departments of Haematology, Digestive Medicine, General Surgery-traumatology, Oncology and Pneumology. During the study period (2015-17), general activity increased in our hospital. Thus, the number of patients hospitalized rose from 17871 to 18111, and the number of patients attended in

the renal clinic (including first visits and follow-ups) rose from 2367 to 2745.

In 2015, prior to the use of NefroConsultor, 333 patients were referred to the nephrology service. In 2017, this number fell to 295, a reduction of 10.1% ($P = 0.001$). Between the two study periods, there were no differences in the patients' age (69.0 years in 2015 versus 67.2 years in 2017, $P = 0.13$), gender ($n = 216$ versus $n = 178$ males, $P = 0.197$), serum creatinine (1.57 versus 1.61 mg/dL, $P = 0.59$), eGFR CKD-EPI (46.2 versus 47.7 mL/min/1.73 m², $P = 0.41$), mean systolic blood pressure (138.4 versus 139.3 mmHg, $P = 0.669$), diastolic blood pressure (72.4 versus 74.3 mmHg, $P = 0.13$) or presence of hypertension [systolic blood pressure (SBP) > 140 or diastolic blood pressure (DBP) > 90], as shown in Table 1. The reasons stated by clinicians for referring patients to the nephrology service were related to the eGFR, proteinuria and albuminuria, CKD-related anaemia, electrolyte disorders and 'other reasons'. The latter were polycystic kidney disease, abrupt or progressive deterioration of kidney function, resistant hypertension, non-urological haematuria, suspicion of genetic CKD, kidney stones or the presence of only one kidney (nephrectomy or discovery).

In 2015, 132 of the 333 patients (39.6%) met the KDIGO criteria and were considered to be correctly referred. In 2017, the corresponding figures were 200 of 295 patients (67.8%) ($P = 0.001$) (see Figure 1). Thus, the rate of intervention success rose by 28.8% (binomial effect size display with a Cohen's *d* effect size of 0.751). On the contrary, a significant number of patients were considered to be incorrectly referred, with eGFR values ranging from 30 to 45 mL/min/1.73 m². Of the 189 patients in Stage 3b 134 did not present other validated criteria such as albuminuria that would lead them to be classed as correctly referred, 100 prior to the use of the app and 34 with the app.

Prior to implementation of the app, 208 of the 333 patients (62.5%) were referred to the nephrology service with study of albuminuria. The corresponding figures for 2017, when the app was used, were 258 of 295 patients (87.5%) ($P = 0.001$). Thus, the rate of intervention success rose by 25.7% (binomial effect size display with a Cohen's *d* effect size of 0.744). Similar improvements were noted for referral data including urinalysis, with a referral rate increasing from 68.5% to 85.8% ($P = 0.001$), representing an increased intervention success of 12.2% (Cohen's *d*: 0.28). Among other primary reasons stated for referral, the presence of proteinuria increased from 23.7% to 34.2% ($P = 0.004$).

Table 1. Baseline characteristics of patients referred as first visits to nephrology clinic in 2015 (before introduction of smartphone app NefroConsultor) and 2017 (after training and with app in use)

Characteristics	Overall (n = 628)	Before app 2015 (n = 333)	Using app 2017 (n = 295)	P-value
Age, years	68.1 ± 15.2	69 ± 14.4	67.2 ± 16.1	0.135
Male sex, n (%)	394 (62.7)	216 (64.7)	178 (60.3)	0.197
Serum creatinine, mean ± SD (mg/dL)	1.59 ± 0.64	1.57 ± 0.59	1.61 ± 0.69	0.591
eGFR, mL/min/1.73 m ² (CKD-EPI)	46.9 ± 21.4	46.2 ± 21.4	47.7 ± 25.6	0.409
Active urinalysis or blood cell casts (yes), n (%)	122 (19.4)	44 ± 19.0	78 ± 31.0	0.004
Albuminuria, mean ± SD (mg/g)	369.8 ± 690.1	368.9 ± 717	370.6 ± 668.4	0.937
Reason for referral				
Proteinuria, n (%)	180 (28.7)	79 (23.7)	101 (34.2)	0.004
GFR, n (%)	409 (65.1)	232 (69.7)	177 (60.0)	0.016
Anaemia, n (%)	4 (0.6)	1 (0.3)	3 (1.0)	0.345
Electrolyte abnormalities, n (%)	3 (0.5)	1 (0.3)	2 (0.7)	0.602
Other, n (%)	131 (20.9)	49 (14.7)	82 (27.8)	<0.001
SBP, mean ± SD (mmHg)		138.4 ± 22.3	139.3 ± 23.0	0.669
DBP, mean ± SD (mmHg)		72.4 ± 12.5	74.3 ± 14.0	0.13
Hypertension, presence SBP >140 or DBP > 90 (mmHg), n (%) (216 not evaluated)	184 (44.7)	81 (42.0)	103 (47.0)	0.351
Referral from (16 unknown provenance)				
Internal medicine, n (%)	283	160 (49.4)	123 (42.7)	0.065
Urology, n (%)	139	60 (18.5)	79 (27.4)	
Cardiology, n (%)	38	22 (6.8)	16 (5.6)	
Other, n (%)	152	82 (25.3)	70 (24.3)	
Referral including kidney ultrasound, n (%)	242	110 (33.0)	132 (44.7)	0.002
Referral including urinalysis, n (%)	481	228 (68.5)	253 (85.8)	<0.001
Referral including data of albuminuria, n (%)	466	208 (62.5)	258 (87.5)	<0.001
Correct referral to nephrology (KDIGO criteria), n (%)	332	132 (39.6)	200 (67.8)	<0.001

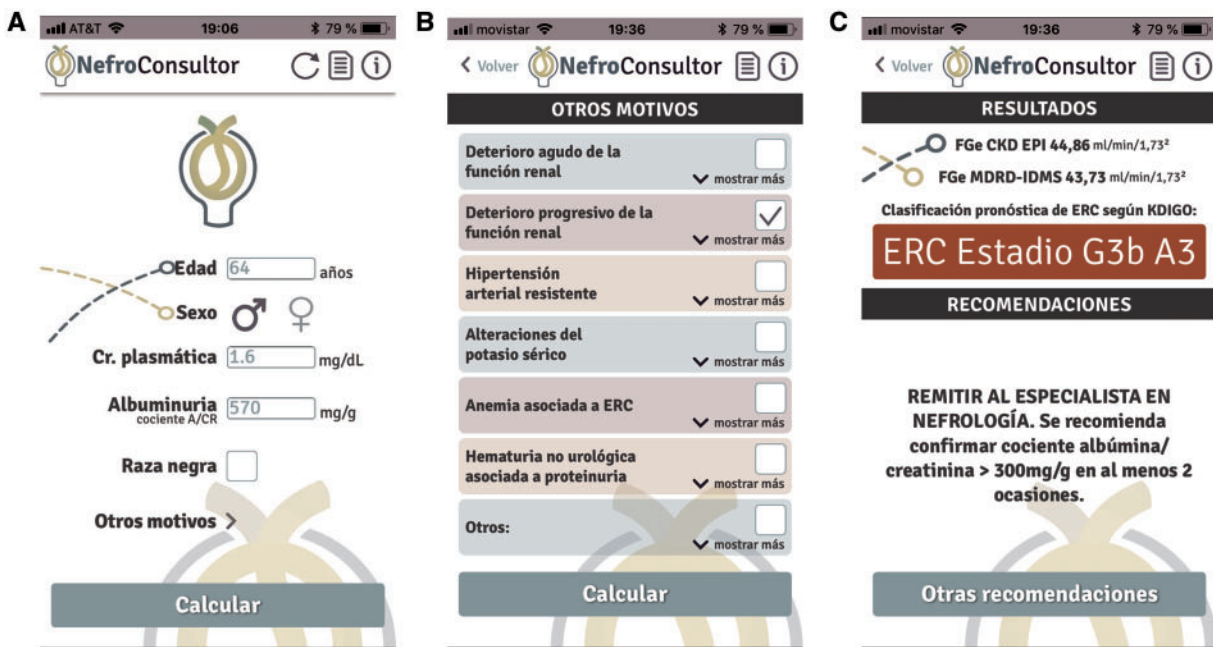


FIGURE 2: Screenshots of NefroConsultor app (smartphone version). First screenshot (A) shows the clinical features requested, namely age, gender, serum creatinine, urine ACR and race. Second screenshot (B) shows 'other reasons': acute or progressive deterioration of kidney function; resistant hypertension and CKD; non-urological urinary red blood cell casts; serum potassium persistent abnormalities; CKD-associated anaemia; suspicion of hereditary CKD or polycystic kidney disease or recurrent/extensive nephrolithiasis. The third screenshot (C) shows stages of CKD, eGFR and recommendation of referral if criteria are met.

Multivariate regression analysis was performed, using referrals meeting KDIGO criteria ('correctly referred') as the dependent variable and adjusting for age, sex and medical department of provenance. The use of the app was associated

with correct referral with an odds ratio of 3.57 (95% confidence interval 2.52–5.05), in the comparison of post- and pre-app referrals ($P=0.001$). In a supplementary analysis, we examined how many patients were asked to return to the renal clinic, in each

of the study years. In 2015, 87 of 201 patients who were 'incorrectly referred' (43.3%) were not asked to return. In 2017, 21 of 95 such patients (22.1%) were not asked to return and received no nephrological follow-up.

DISCUSSION

A smartphone app can be a useful tool, making information more accessible to clinicians in areas such as the indications and timing of referral for patients with CKD. In our study, implementation of the app improved referral rates from 39.6% to 67.8%, highlighting the currently inadequate knowledge of referral guidelines. After physicians were introduced to the NefroConsultor app, their patients were more frequently referred to the nephrology service with albuminuria and urinalysis data (87.5 and 85.8%, respectively, in 2017 versus 62.5 and 68.5%, respectively, in 2015). In both years, most patients were referred because of low levels of eGFR, but references to proteinuria as a reason for referral increased by 10.5% during the study period. The implementation of this kind of healthcare app for use in mobile devices contributes to clinical practice and referral decisions, and can also help unify criteria and coordinate the different medical departments involved in treating CKD and other diseases.

Late nephrology referral may be due to unavoidable causes, such as the referral biases of clinicians, socioeconomic status, patient factors or differences between healthcare systems [16–18]. However, other factors, such as insufficient training regarding the guidelines on timing or indications for referral, can be addressed, as we show in this study. Evidence-based guidelines provide valuable indications for nephrology referral, and so it is of great importance to make this information simple and accessible. In our opinion, apart from the question of early or late referral, a correct decision based on available evidence should be taken, and for this purpose, a focused smartphone app can be a very useful instrument. Although other nephrology-related apps, such as iChoose Kidney, have been evaluated in randomized controlled trials focusing on a shared decision aid designed to be used by clinical providers (including physicians) and their patients [19], to our knowledge, NefroConsultor is the first app-based decision-making aid to help non-specialists decide whether a patient should be referred to the nephrology service.

Furthermore, NefroConsultor highlights problems that should be considered and overcome in future referral guidelines and recommendations. For example, a 19-year-old female with serum creatinine of 1.9 mg/dL, leukocyturia and ACR of 200 mg/g does not meet current criteria for nephrologist evaluation. Young patients with renal disorders such as tubulointerstitial nephritis or glomerulonephritis in remission and who characteristically have low albuminuria and only mild deterioration of kidney function may go unnoticed. Current KDIGO guidelines [4] underestimate the risks in younger patients with these kidney diseases, who in our opinion should also be referred for nephrological evaluation. Future guidelines should consider and address these issues. Early referral may also reduce both costs and mortality [5–12]. In our opinion, nephrologists should play a more prominent role in preventing CKD and in slowing progression of the disease. Interestingly, in our study, a large proportion of patients (over 50%) who did not meet the current KDIGO criteria for referral were actually evaluated by a nephrologist and were asked to continue follow-up at the renal clinic.

A major limitation of our analysis, and one that is common to all pre–post studies, is the inability to control other elements that may be changing at the same time as the intervention

being examined. In our case, for example, the nephrology referral guidelines may have become more widely known during the intervention, and this factor might account for the higher quality nephrology referrals that we report. Accordingly, randomized controlled trials should now be undertaken to better determine the effectiveness of NefroConsultor. Among other limitations, referral patterns are not uniform across healthcare systems or geographical regions. We believe referral should only be determined by concern for the patient's wellbeing, and should not be related to the characteristics of the healthcare system. Ensuring that referral meets adequate criteria, by means of tools such as this smartphone app, could help in this respect. A further limitation to our study is the fact that all our referrals were from hospital departments, with none from general practitioners. Nevertheless, this fact, together with the low number of clinicians involved, helped us to accurately monitor the use made of the app training programme by members of the different medical specialties in the hospital. These issues, as well as a consideration of the possible reduction in costs, morbidity and mortality that might be achieved by means of the intervention we describe, require further investigation. Despite these limitations, our study shows that the use of the app 'NefroConsultor' reduces the number of referrals to the nephrology service and improves the identification of patients at risk. This enhanced situation has been achieved despite the increased activity in the hospital (numbers of patients hospitalized and attended in the renal clinic, including follow-ups) during the study period. Thus, referrals in accordance with KDIGO criteria increased by 28.2%. Interestingly, albuminuria and urinalysis studies at the time of referral were also conducted more frequently, and proteinuria was increasingly cited as a reason for referral. Hence, more at-risk patients were identified. Further research, based on randomized prospective trials, should be conducted to examine and potentially confirm the contribution of our study findings, and to expand the scope for this sort of technological advance, which at present still has a very limited impact on health outcomes.

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CONFLICT OF INTEREST STATEMENT

The authors E.O.-D., N.O.-D. and J.P. developed the app *NefroConsultor*, which is endorsed by the Spanish Society of Nephrology. They do not obtain any economic benefit from the app, which is a free download available from Google Play and the App Store. J.C.R.-P. received honoraria from Abbvie. All the other authors declare they have no competing interests.

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