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Percutaneous Coronary Intervention Versus Optimal Medical Therapy for Stable Angina in Advanced CKD: A Decision Analysis

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Abstract

Background—Utilization of percutaneous coronary intervention (PCI) is low in the setting of stable symptomatic angina in individuals with advanced chronic kidney disease (CKD) despite high cardiovascular risk in this population, and PCI is frequently deferred out of concern of precipitating dialysis. Whether this is appropriate is uncertain, and patient-centered data comparing the relative risks and benefits of continued medical therapy vs PCI in patients with advanced CKD and stable angina is scarce.

Study Design—Decision analysis.

Setting & Population—Hypothetical cohort of individuals with advanced CKD (stages 4–5 with eGFR ≤20 ml/min/1.73m^2) and stable angina.

Model, Perspective, & Timeline—A Markov model with a Monte Carlo simulation through 12 cycles, i.e. 3 years of 3-month intervals, with 10,000 micro-simulations predicted mean quality-adjusted life-years (QALYs).

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Intervention—PCI first, medical management (MM), or dialysis (hemodialysis [HD]) followed by PCI.

Outcomes—Outcomes modeled were progression to HD (for those not assigned to the preemptive HD strategy), catheter infection, and death.

Results—Our analysis showed mean QALYs of 1.103±0.69 for the PCI first, 1.088±0.70 for MM, and 0.67±0.58 for the HD followed by PCI strategy. Probabilistic sensitivity analysis (PSA) found PCI as the preferred strategy >60% of the time.

Limitations—Values for probabilities and utilities were estimated and/or derived from multiple sources that were not uniform in their populations in terms of age, comorbidity burden and degree of kidney failure, and several simplifying assumptions were made.

Conclusions—Our analysis demonstrates that quality-adjusted life expectancy is similar for PCI first and MM strategy in advanced CKD with stable angina and that the decision depends on patient preferences other than those incorporated in our model. Both strategies are superior to pre-emptive dialysis.

Keywords

percutaneous coronary intervention (PCI); advanced renal failure; chronic kidney disease (CKD); cardiovascular intervention; contrast nephropathy; contrast-induced nephropathy (CIN); stable angina; medical management; quality of life; quality-adjusted life-year (QALY); hemodialysis; catheter infection; death; mortality; therapeutic nihilism; decision model

Individuals with advanced chronic kidney disease (CKD) have high prevalence of coronary artery disease (CAD)[1,2] and may benefit from cardiovascular procedures like percutaneous coronary intervention (PCI) that requires the use of intravenous contrast. On the other hand, contrast dye can cause contrast-induced nephropathy (CIN), an especially important complication in individuals with advanced CKD in whom CIN may precipitate the need for long-term dialysis (hemodialysis [HD]).[3,4] While PCI is frequently offered to individuals with CKD in the setting of unstable coronary syndromes where a survival advantage to early intervention has been demonstrated,[5,6] both patient and physician factors contribute to a decreased utilization of PCI in the setting of stable symptomatic angina where PCI is often deferred until necessitated by acute indications or until dialysis has been initiated. In fact, several studies have demonstrated a decreased tendency to perform diagnostic or interventional coronary catheterization in patients with CKD, thought to signify “renalism” which is a therapeutic bias against aggressive therapy in CKD patients.[7,8]

Several factors may underlie the low utilization of PCI in CKD. Patients and their physicians must balance the risk of morbidity and mortality from non-revascularized CAD against the risks of PCI, and the potential for morbidity and mortality following semi-urgent dialysis initiation. Thus, depending on the assessment of quality of life (QoL) outcomes with each of these possibilities, a decision to tolerate incomplete angina relief rather than engender the risk of earlier initiation of HD following a PCI may represent appropriate, patient-centered clinical decision making rather than therapeutic nihilism. In our clinical experience, concerns that PCI could precipitate rapid progression to dialysis frequently deter patients with advanced CKD or their physicians from potentially beneficial invasive coronary

procedures in the setting of stable angina. Although this dilemma is common, randomized data comparing the relative risks and benefits of continued optimal medical therapy (OMT) and PCI in patients with advanced CKD and stable angina are scarce. We therefore performed a patient-centered decision analysis modeling upfront PCI compared with the options of deferring catheterization and continuing medical management (MM) only, or pre-emptive HD followed by cardiac catheterization in patients with ongoing angina despite initial medical therapy.

Concise Methods

Decision Tree

A decision analytical model was created with three branches, each representing a treatment strategy for a patient with advanced CKD (eGFR ≤20 ml/min/1.73m^2, which would mean that patients had stage 4 or 5 CKD) with stable angina despite initial medical therapy, using TreeAge Pro software, version 2015: a) proceeding to PCI and commencing HD only if needed b) deferring PCI and HD in favor of MM; and c) initiating HD via a tunneled catheter prior to catheterization. In the first and second cases, HD was to be initiated only if indicated—that is, if CIN or sub-acute progression necessitated dialysis.

For the purpose of this analysis, the following assumptions were made: a) the patient has had a non-invasive test or other clinical event providing an indication for intervention or MM, b) non-invasive findings are suggestive of discrete lesions amenable to PCI (i.e. low risk coronary anatomy with no ECG changes diagnostic of acute myocardial infarction and no clinically obvious unstable angina) to avoid uncertainty regarding appropriateness of PCI versus coronary artery bypass grafting, and c) No permanent access such that catheter placement would be required for HD initiation. Model time horizon was 12 cycles (i.e. 3 years with 3-month intervals). The probabilities modeled included the likelihood that the chosen intervention(s) result in immediate death, alleviate symptoms of angina, or precipitate HD. Furthermore, the likelihood of catheter infection, the risk that catheter infection will be fatal, the probability of progression of underlying CKD to HD, and the likelihood of death from other causes was incorporated into the model.

Probability and Utility Estimates

Probability of successful intervention was derived from the post hoc analysis of Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) study,[9] which showed that in patients with CKD, 76% from the PCI-plus-OMT group and 70% patients on OMT alone were angina free at 36 months (Table 1). A meta-analysis of 14 randomized trials addressing PCI versus MM showed lower success rates for MM (63.9% versus 73% for PCI), however the majority of studies included in this meta-analysis were in the non-CKD cohort.[10] Recently Gupta et al[11] showed that probability of procedural death from PCI in stable ischemic heart disease is 1% for CKD patients and 1.8% for end-stage renal disease (ESRD) patients. Probability of death from MM was estimated to be 0.0001 from clinical practice-based observations.

Probabilities of all-cause mortality in advanced CKD and HD patients were derived from the 2014 US Renal Data System (USRDS) report in which the 2012 adjusted mortality rate for patients with CKD stages 4–5 was 115/1000-patient-years (ranging from 76/1000-patient years in patients with CKD stages 4–5 but without diabetes and cardiovascular disease (CVD) to as high as 176/1000-patient years in those with both diabetes and CVD).[12]

Similarly, for incident HD patients, the risk of death was 421/1000 person-years for the first two months and 193/1000 person-years for the remainder of the first year on dialysis.[12] Rates were converted to probabilities using the formula→ $p=1-e^{-rt}$ where "p" is probability; "r" is instantaneous rate, provided that it is constant over the period of interest "t".

Rate of progression of CKD to ESRD is dependent on many factors including age, gender, race and comorbidities.[13] Based on a prospective cohort study by Landray et al[14], annual probability of progression to ESRD ranges from 9.6% for CKD stage 4 to 58.2% for CKD stage 5. Graphical data review from Hallan et al[15] showed similar results with average ESRD progression of ~300/1000 patient-years. Therefore, a mean annual progression rate of 30% was used in our base model.

The risk of CIN among advanced CKD patients and the risk of precipitating HD should CIN ensue was derived from cohort studies of advanced CKD patients that estimated a CIN probability of approximately 20%[4,16]; however, only 0.3–9.8% of these patients require HD based on multiple patient factors including baseline eGFR.[4,17–21] In one smaller study dialysis-requiring CIN (CIN) was as high as 15%.[6] As a simplifying assumption, we used the highest end probability of dialysis-requiring CIN of 15%. These assumptions were subsequently relaxed and probabilities were allowed to vary in sensitivity analyses.

Catheter-related bacteremia and the fatality rate of catheter infections was modeled based on a cohort study of incident HD patients, which estimated 1 year probability of catheter infection to be 60%[22]. Graphical data inspection revealed that the probability plateaued at 270 days, with an approximately linear risk up until that point.[22] We therefore estimated the 3-month probability of catheter infection to be 20%. Although our base case assumed that all patients initiate with a catheter, sensitivity analyses examined initiation with an arteriovenous fistula (AVF). Annual risk of infection with AVF is lower and estimated to be ~0.9%.[23] In addition, a contemporary meta-analysis found that annual event risk of fatal infection with fistulas is 3% compared to approximately double the risk (6%) with catheters.[24]

Utilities of Angina, CKD, HD, and Combined States

Unrelieved angina symptoms were estimated as having a utility of 0.7725 (Table 1).[25,26] Utility for non–dialysis-dependent CKD was estimated at 0.85 using the time trade-off method. [27] Davison *et al*[28] showed that the utility for CKD stages 4–5 using the Health Utilities Index Mark 3 (HUI3) tool and the preference based scoring system SF-6D is 0.58 and 0.67, respectively. A decision analysis by Hiremath et al[29] used utilities of 0.62 for CKD stage 4, with and without AVF, and a utility of 0.51 for dialysis. We therefore used an average utility of 0.62 for CKD and a utility of 0.51 for dialysis. For simplicity, we assumed

that a non-fatal catheter infection does not change the utility of HD. We assumed that utilities were independent and therefore multiplicative so, for example, multiplied uAngina by uCKD to yield uTotal for the unrelieved angina with CKD state.

Model Building

A Markov model was constructed for the four possible advanced CKD and angina intervention states: CKD and PCI (no CIN or CIN without dialysis needs), CKD and MM, HD and PCI (either pre-emptive or after dialysis-requiring CIN which was assumed to be instantaneous), and death (Figure 1 a and b). Prior to the Markov node, we inserted chance nodes for death from the chosen intervention as well as probability of successful intervention (i.e. angina relief or persistent angina). Because individuals with a catheter could have recurrent catheter infections, a tracker variable was used to track the number of catheter infections. We assumed that after one year on dialysis everyone would have a permanent access. The model was analyzed using Monte Carlo micro-simulation with 10,000 trials to obtain mean expected quality-adjusted life-years (QALYs) for each option.

Sensitivity Analyses

A sensitivity analysis of dialysis-requiring CIN risk was conducted using a triangulated distribution with minimum probability of 0.01, most likely of 0.03 and maximum of 0.15 based on the aforementioned sources. We altered the probability of infection to 0.9% to reflect the risk with an AVF. Finally, we conducted probabilistic sensitivity analyses (PSA) with 10,000 Monte Carlo simulations (2^{nd} order simulations) on the triangular distributions for each utility, on the probabilities of dialysis-requiring CIN risk and catheter infection, probability of successful relief of angina symptoms with MM alone and with PCI, annual probability of progression of advanced CKD to ESRD, mortality risk with PCI procedure and mortality rates of CKD and ESRD. Reported values in the literature were used as the likeliest values, and minima and maxima were derived from ranges available. Alternatively a 10% variation range was used for key inputs where distributional statistics were not reported. We applied 3% discounting post 1 year of model-time.

PSA was chosen to estimate uncertainties because it plays an analogous role in decision analysis to the use of statistical inference in epidemiology and regression modelling.[30] PSA is considered the gold standard for assessing and measuring uncertainty in decision analysis in order to account for the scale of uncertainty and to elucidate the full distribution of the key parameters subject to reservations.[31] PSA thus provides the best estimate and is meant to inform on the mean net benefit of a decision despite residual uncertainties surrounding the model.[30]

Results

The base model yielded mean QALYs of 1.103±0.69 for the PCI first strategy, 1.088±0.70 for MM, and 0.67±0.58 for HD followed by PCI (Table 2). The results favored PCI more when a more likely estimate of dialysis-requiring CIN risk was used.

Tracking the number of catheter infections highlighted the expected result that those preemptively initiated on HD had more catheter infections than those on MM or receiving

PCI first (Table 3). Sensitivity analysis on the initial dialysis access (AVF versus catheter, with the former choice lowering the probability of bloodstream infection) showed PCI first providing marginally higher utility to MM (PCI first,1.09; MM, 1.08; and HD then PCI, 0.65). Based on multiple sensitivity analyses using higher probabilities of catheter infection, there was no plausible risk of infection even with temporary catheters that would result in MM being favored over the PCI first strategy. Attempts to identify a threshold probability for dialysis-requiring CIN risk at which MM and PCI first would have approximately equal QALYs yielded a value of 13.9% (Figure 2).

PSA on triangular distributions of the three utilities (uAngina, uCKD, uHD) along with other variable probabilities (Table 1) yielded similar results to our base model with mean QALYs of 1.182±0.16, 1.137±0.15, and 0.914±0.24 for PCI first, MM, and HD then PCI strategies, respectively. Varying annual range of probability of progression of advanced CKD to ESRD from 9%–100% in the base model showed that PCI was the preferred strategy when rate of progression was greater than 9.6% (Table 4). The QALYs remained higher for PCI first than for the MM strategy, even when the model was limited to 3 months, 6 months or 1 year instead of 3 years, but differences were marginal (Table 5). Preemptive HD followed by PCI was never the preferred decision in any analysis. PSA demonstrated that PCI was the preferred strategy >60% of the time (Figure 3). The expected value of perfect information using PSA was low at 0.0017.

Discussion

The optimal therapy for individuals with advanced CKD and stable angina not responding sufficiently to MM has not been adequately defined in clinical trials or in epidemiologic studies. In the absence of adequate data reflecting patient-centric fears of precipitating HD with immediate PCI, it is our experience that patients and physicians frequently defer interventional therapy in the setting of advanced CKD with the belief that tolerating angina is better than starting dialysis.

Whether this strategy improves patient-centered outcomes is uncertain. We therefore performed a decision analysis comparing three different therapeutic interventions: proceeding to PCI and initiating HD only when justified by severity of CIN or natural disease progression, deferring PCI and HD in favor of MM, or immediately initiating HD via a tunneled catheter prior to cardiac catheterization, in advanced CKD with stable angina. The major conclusion of our analysis is that quality-adjusted life expectancy is similar for PCI first and MM. Gains with PCI first were consistent in our analyses but of marginal clinical significance, suggesting that the decision should depend on patient preferences other than those incorporated in our model. Both strategies were clearly superior to pre-emptive HD. Dialysis should therefore be performed only if kidney function declines secondary to CIN or downstream progression of disease warrants renal replacement therapy. For those with advanced CKD and symptomatic stable angina, PCI should be offered, and patients and their caregivers should be reassured that deferring coronary interventions due to the risk of CIN and fear of precipitating dialysis-dependence or pre-emptively initiatiing HD to counteract that risk may be counterproductive if the goal is to improve overall well-being.

The QALYs were marginally higher with the PCI-first strategy regardless of the type of access, likely reflecting marked decrease in utility and QoL that occurs with HD initiation. Nevertheless, the high number of catheter infections suggests that strategies to minimize infection, including, but not limited to, preemptive AVF placement, may further maximize expected QoL.

Compared with MM, PCI showed marginally higher QALYs when the model time-horizon was limited to 3, 6 or 12 months. Thus, our results suggest that for individuals specifically meeting our base-case definition of residual angina despite MM, a preference for dialysis avoidance over better angina relief and a decision to avoid PCI is not likely to be associated with better outcomes in either short-term or long-term time-frames. Conversely, improvement in outcomes with PCI appears to be small, suggesting that either PCI or MM are acceptable alternatives and that patient preferences or factors other than those modeled (e.g. the severity of angina) may be critical to maximizing patient-centered outcomes. In this vein, the decrement in QoL from even a few additional weeks of angina was a dominant factor in determining the slightly greater QALY after initial choice. Thus, as an example, PCI may be the preferred strategy of these therapeutic alternatives when angina is unremitting and severe, whereas either therapy may be reasonable when angina is less severe or frequent.

The results of the International Study of Comparative Health Effectiveness With Medical and Invasive Approaches–CKD (ISCHEMIA-CKD; NCT01985360 at ClinicalTrials.gov), a randomized trial to determine optimal management strategy for patients with advanced CKD and stable ischemic heart disease, are likely to provide important answers to some of these questions, though results are unlikely to be available for several years. In the meantime, our analysis provides some reassurance about performing non-urgent PCI in patients with advanced CKD where there may be incomplete angina relief despite initial MM.

The results of this study are in accordance with a meta-analysis of 12 randomized trials comparing PCI to OMT. Compared with OMT alone, PCI provided greater angina relief. However, there was no difference in mortality, cardiovascular death, or nonfatal myocardial infarction between the two groups.[32] These results appear to be consistent in CKD. A post hoc analysis of the COURAGE study by Sedlis et al compared health status in CAD patients with and without CKD using the Seattle Angina Questionnaire. The score was higher with PCI plus OMT versus OMT alone, irrespective of baseline CKD status.[33] In the subgroup analysis of COURAGE, PCI with OMT did not reduce the risk of myocardial infarction and death but it was also not associated with worse outcomes compared to OMT in patients with moderate CKD.[9]

The higher expected value of performing PCI in patients with advanced CKD with stable angina, even taking into account CIN risk, adds credence to the notion that addressing “renalism” could offer opportunities to improve clinical outcomes in a high-risk population.[34] Much of the hesitation in performing PCI in advanced CKD patients stems from concerns related to the short- and long-term adverse consequences of CIN, including the need for dialysis, increased length of hospitalization, major cardiac events, and mortality.[19,35] However, most studies report a CIN incidence of 0.6%–20%, with rates in the

higher end of the range in those with significant CVD, advanced decrease in kidney function and/or diabetes. Furthermore, of those with CIN, a very small number require dialysis. We used a worst-case scenario of dialysis-requiring CIN rate of 15% in our base case analysis that, not surprisingly, showed nearly equivalent results for the PCI first and MM strategy. Although there may be rare individuals with risk of dialysis-requiring CIN higher than 14% (threshold for dialysis-requiring CIN risk at which PCI and MM is approximately similar), PCI is likely to be the preferred strategy under more likely estimates of dialysis-requiring CIN risk, in which case our analysis may underestimate the advantage of PCI compared to MM.

PSA showed that PCI first was the preferred decision >60% of the time. It is important to note that PSA on probabilities of key inputs and utilities for the states yielded a very low expected value of perfect information, suggesting that research aimed at obtaining more precise estimates would be unlikely to qualitatively change our findings.

Our analysis does not identify subgroups in which strategies other than PCI first would be preferred. For example, the answer is likely to differ in a CKD patient with *de novo* angina never treated medically. In this case, there may be a greater likelihood of relieving angina with OMT alone compared to our base case in which there is residual angina after medical therapy. Given procedural risks of PCI and trials demonstrating equivalent survival with PCI and MM in the general population as well as those with moderate CKD,[36] there should be minimal risk in delaying PCI and initiating MM. Analyzing a delayed crossover strategy from MM to PCI within a formal Markov model is technically challenging and unlikely to be clinically informative given available data and the availability of medical therapies with a high likelihood of resolving angina in patients without prior MM.

Limitations of our analysis should be acknowledged. The values for probabilities and utilities were estimated and/or derived from multiple sources, and we made several simplifying assumptions (i.e. that probability of catheter infection is the same over successive 3-month periods, and that a permanent access would be placed after 1 year). Furthermore, the values were extrapolated from studies not uniform in terms of age, comorbidity burden and degree of kidney failure. However, our results were consistent in extensive sensitivity analyses in which these rates were varied widely. Furthermore, uncertainties in probabilities were estimated using PSA, which is considered the gold standard for assessing and measuring uncertainty in decision analysis given that one-way sensitivity analysis alone cannot account for the scale of uncertainty or elucidate the full distribution of the key parameters subject to reservations.[31] The net difference in the QALYs between the PCI and MM strategy appear small and may represent a “toss-up”.[37] PSA and expected value of perfect information provide confidence that, given clinical uncertainties about the risks and benefits of PCI and OMT in the setting of CKD, a strategy of PCI first is not likely to decrease overall QoL compared with MM when there is a need to decide between these options. However, given uncertainty about individual CIN risk, and the small difference between MM and PCI strategy, it may be challenging to convey the differences to patients who want the “best choice” and a decision will need to be tailored.

Several of our assumptions or simplifications, including the nature of the coronary lesions (implications of non-invasive testing, amenability to PCI, etc) and the decision to force individuals to remain with a catheter for one year (rather than allowing for AVF to be placed sooner) may limit generalizability. The results of this analysis thus are most relevant to patients with stable angina with a low risk coronary anatomy in the presence of advanced CKD. To evaluate the risk and to find the best interventional approach (e.g. PCI versus coronary artery bypass grafting) that will yield the highest QALYs for an advanced CKD patient with a more complicated cardiovascular presentation (i.e. acute myocardial infarction or unstable angina, high risk stress test, recent PCI suggesting a higher probability of requiring surgery or other acute clinical findings requiring hospitalization), will require a different model and calculus.

The decision about how to manage stable symptomatic angina in advanced CKD should be designed to maximize QoL at least from the patient perspective, but data to guide decision-making from this vantage point are sparse. Our findings suggest that conservative approaches that limit the use of PCI in order to protect kidney function should be reevaluated and revisited. We believe that the results of our study may help guide both physicians and patients to make a more informed decision and should mitigate apprehension in regards to risk of coronary intervention in patients with advanced CKD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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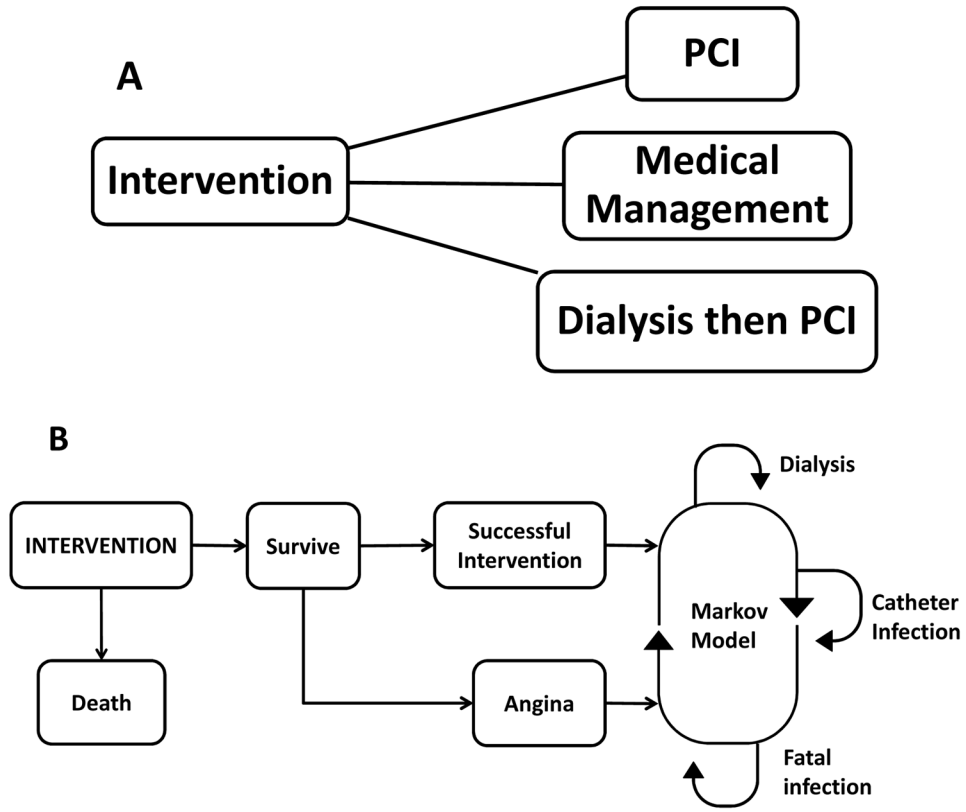

Figure 1. Conceptual Model of the Decision Analysis

Patients are assigned to 1 of 3 treatments as shown in the Decision tree (A). Following an initial treatment choice, subjects cycle through the possibilities shown in the Markov model (B). PCI- percutaneous coronary intervention.

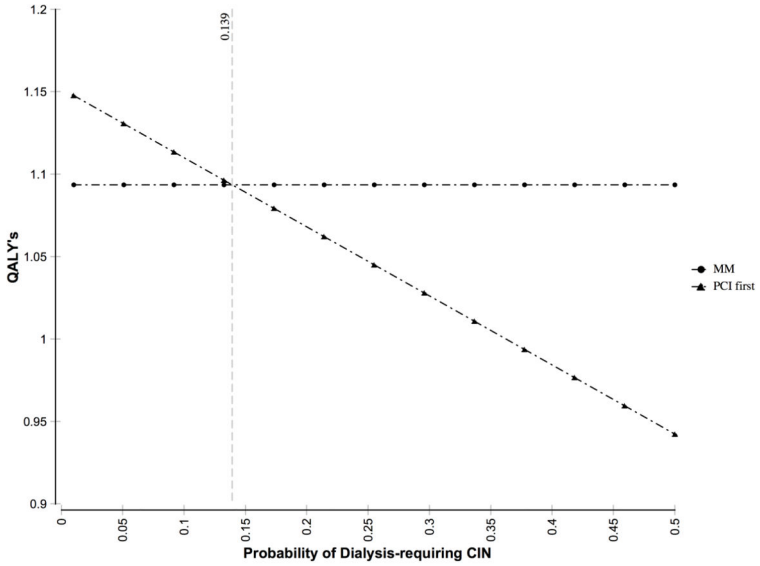

Figure 2. Impact of dialysis-requiring contrast induced nephropathy (CIN) rate on treatment choice

The impact of varying the rate of dialysis-requiring CIN upon optimal treatment strategy is shown. Threshold probability for dialysis-requiring CIN risk at which MM and PCI first would have approximately equal QALYs is 0.139. PCI-percutaneous coronary intervention; MM-medical management; CIN- contrast induced nephropathy; QALY-quality-adjusted life-year.

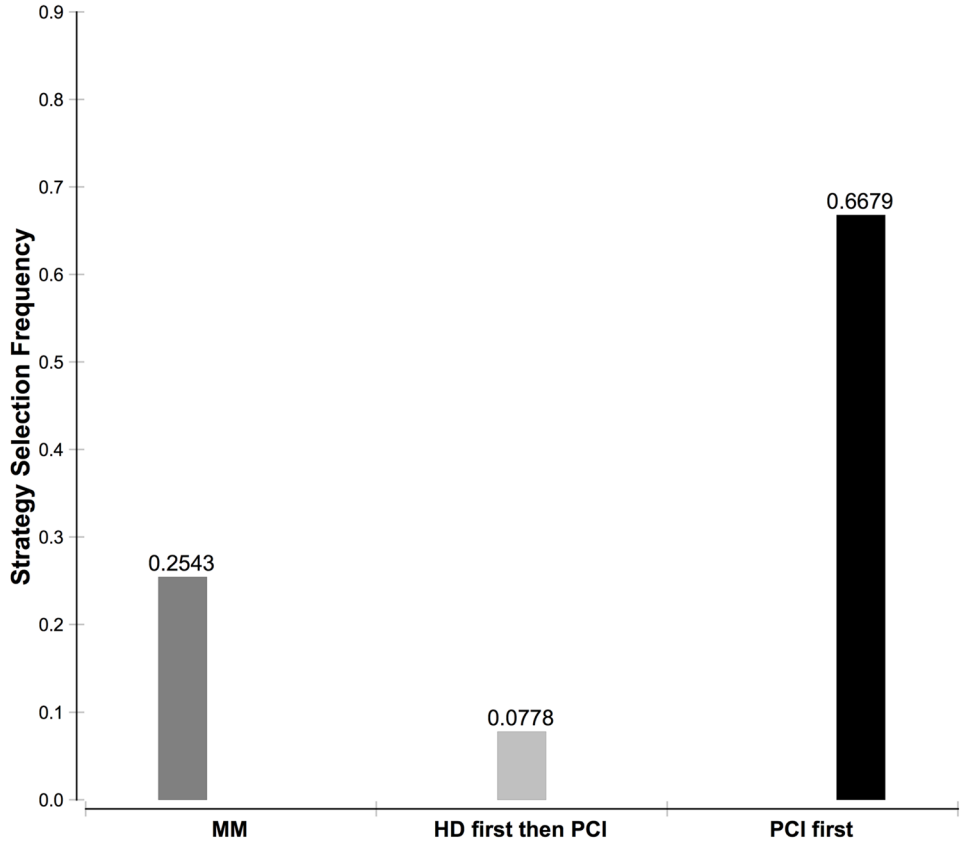

Figure 3. Strategy Selection Frequency

Strategy selection frequency by Probabilistic sensitivity analysis. MM-medical management; HD-hemodialysis; PCI- percutaneous coronary intervention; CKD- chronic kidney disease.

Table 1

Utilities and Probabilities

Input	Value	Reference(s)	Range in PSA
Probabilities			
Successful medical management	0.70	Sedlis 2009	10% variation
Successful PCI	0.76	Sedlis 2009	10% variation
Death from medical management	0.001	Clinical observation	-
Death from PCI procedure	0.01	Gupta 2015	0.003–0.018
Progression of advanced CKD to HD	0.30/y	Landray 2010, Hallan 2012	0.096–0.582
Death in advanced CKD	115/1000 pt-y	2014 USRDS	76–176/1000 pt-y
Death in HD initiation	421/1000 pt-y	2014 USRDS	-
Death in long-term HD	193/1000 pt-y	2014 USRDS	79–421/1000 pt-y
Catheter infection	0.20/3-mo	Lee 2005	10% variation
Death from catheter infection	0.06	Ravani 2013	-
Dialysis-requiring CIN	0.15	Marenzi 2004, Dangas	0.01–0.15
Utilities			
Utility with angina	0.7725	Lalonde 1999	0.7–0.8
Utility with CKD stage 4	0.62	Hiremath 2011	0.40–0.84
Utility with HD	0.51	Hiremath 2011	0.20–0.82

PSA-probabilistic sensitivity analysis;; PCI: percutaneous coronary intervention; CKD: chronic kidney disease; HD: hemodialysis; CIN: contrast-induced nephropathy; pt-y, patient-year

Table 2

Results

Analysis	PCI first	Medical Management	HD then PCI
Base-case: 15% dialysis-requiring CIN risk	1.103±0.69 (1.94)	1.088±0.70 (1.89)	0.67±0.58 (1.32)
Base-case: 3% dialysis-requiring CIN risk	1.132±0.69 (1.96)	1.092±0.70 (1.88)	0.66±0.58 (1.32)
PSA	1.182±0.16 (2.07)	1.137±0.15 (1.99)	0.914±0.24 (1.83)

Note: Values are given as quality-adjusted life-year ± standard deviation (life-year).

PCI: percutaneous coronary intervention; HD: hemodialysis; PSA-probabilistic sensitivity analysis; CIN: contrast induced nephropathy

Table 3

Event Rates per a 3-year Model-time

Event	PCI first	Medical Management	HD then PCI
Catheter Infection	0.045 ±0.22	0.025 ±0.16	0.16 ±0.40
Fatal Catheter Infection	0.0009 ±0.02	0.0006 ±0.02	0.0027 ±0.05
Progression to HD	0.45 ±0.49	0.52 ±0.49	0
Death other	0.47	0.44	0.64

Note: Values are given as rate ± standard deviation or rate.

PCI: percutaneous coronary intervention; HD: hemodialysis;

Table 4

QALYs by CKD progression rate

Annual probability of CKD progression	PCI first	Medical Management	HD then PCI
9.6 %	1.167±0.73	1.168±0.73	0.65±0.58
30%	1.103±0.69	1.088±0.70	0.67±0.58
58.2%	1.027±0.66	1.013±0.67	0.67±0.59
100%	0.954±0.62	0.933±0.63	0.68±0.59

Note: Values are given as quality-adjusted life-year ± standard deviation.

PCI: percutaneous coronary intervention; HD: hemodialysis; QALY: quality-adjusted life-year

Table 5

QALYs by Model Time-Horizon

Time-Horizon	PCI first	Medical Management	HD then PCI
3 mo	0.24±0.03	0.23±0.03	0.19±0.05
6 mo	0.35±0.05	0.34±0.05	0.28±0.07
12 mo	0.55±0.07	0.53±0.07	0.44±0.11

Note: Model time horizon by probabilistic sensitivity analysis. Values are given as quality-adjusted life-year ± standard deviation. PSA-probabilistic sensitivity analysis;

PCI: percutaneous coronary intervention; HD: hemodialysis; QALY: quality adjusted life-year