Decreasing Rates of Acute Kidney Injury After Percutaneous Coronary Interventions Through Education and Standardized Order Sets in a Large Tertiary Teaching Center

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Abstract: Acute kidney injury (AKI) is a common complication of percutaneous coronary interventions (PCI), and it is associated with increased morbidity, mortality, and healthcare costs. Post-PCI AKI is a major quality outcome measured by the National Cardiovascular Data Registry for hospitals that perform PCI. We report the experience of a large, tertiary center with high standardized, post-PCI AKI rates in which we implemented multilevel interventions that included: (1) a multidisciplinary education module for all personnel involved in care of patients undergoing cardiac angiography, (2) a standardized electronic medical record based preprocedure hydration protocol order set for patients undergoing cardiac angiography, and (3) a hydration task list to be completed by the care team the evening before the procedure or prior to admission. All this resulted in a constant

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decrease of the post-PCI AKI rates in remarkable magnitude, significantly stronger than the national tendency, demonstrating a center-specific behavior. (Curr Probl Cardiol 2021;46:100453.)

Introduction

Acute kidney injury (AKI) after percutaneous coronary interventions (PCI) is a well-known complication, and is associated with increased morbidity, mortality, and healthcare costs.[1,2] The risk of developing post-PCI AKI depends on a variety of clinical and procedural factors. These include contrast volume and complexity of the procedure, along with other clinical features such as diabetes, hemodynamic status, and presence of cardiogenic shock.[2] The risk of post-PCI AKI may be mitigated by adequate hydration starting prior to the procedure and by limiting the amount of contrast used.

Post-PCI AKI is one of the major quality outcomes measures identified by the National Cardiovascular Data Registry (NCDR) for hospitals that perform PCI. Our institution is a high-volume, tertiary care teaching center in Houston, TX (Memorial Hermann-Texas Medical Center; MHH-TMC) and forms the hub of a large referral network for acute ST-elevation myocardial infarction care. As such, our unadjusted rates of post-PCI AKI are expected to be higher than the national median. Nevertheless, the incidence of post-PCI AKI at MHH-TMC remained higher than the national median even after statistical adjustment for the variables included in the NCDR's CathPCI registry. That observation prompted us to improve the standard periprocedural protocols and then evaluate the impact of these interventions on the incidence of post-PCI AKI.

Methods

Multilevel interventions included development and implementation of: (1) a multidisciplinary education module for all personnel involved in care of patients undergoing cardiac angiography, (2) a standardized electronic medical records (EMR) based preprocedure hydration protocol (PHP) order set for patients undergoing cardiac angiography, and (3) a hydration task list to be completed by the care team the evening before the procedure or prior to admission.

Healthcare Personnel Education

The educational module was designed by a multidisciplinary team consisting of physicians, nurses, and midlevel providers. It contained information about the clinical impact of post-PCI AKI on patient outcomes, risk factors associated with post-PCI AKI development, and strategies known to reduce its incidence. The module was used to educate all personnel involved in care of patients undergoing coronary angiography at all locations, such as the cardiac catheterization laboratory, recovery area, and cardiovascular critical care and step-down units.

EMR-based PHP

The PHP consisted of a 250 mL bolus of 0.9% NaCl solution to be administered 3 hours prior to the procedure, followed by a continuous infusion of 75 mL/h for all in- and outpatients without heart failure, or heart failure with NYHA Classes I or II. The order set advised the nursing staff to contact the provider for further hydration instructions if the patient had more severe heart failure (NYHA Class III or IV).

Hydration Task List

To improve compliance with the PHP, night shift nurses were instructed to complete a task list that included checking if the PHP had been ordered for patients scheduled to undergo coronary angiography. If not, then the nurse had to contact the medical team to request the order set.

The PHP protocol was initiated during the second quarter (Q2) of 2015. We followed the AKI Network definition of AKI as endorsed by the NCDR, that is: an absolute increase of $\geq$0.3 mg/dL, or relative increase of $\geq$50% in serum creatinine.[3,4] The data for all patients were submitted to the NCDR's CathPCI Registry. NCDR's quarterly outcome reports were obtained, which included risk adjusted rates of post-PCI AKI, to compare MHH-TMC performance between Q2 of 2015 and Q4 of 2016 in respect to national 50th and 90th percentiles (p50 and p90, respectively) of centers in the same range of PCI volume than MHH-TMC. Q1 of 2015 was included in the data set as a reference of the incidence of post-PCI AKI prior to the intervention.

Statistical Methods

Comparison of means and regression slopes between groups was performed using 1-way ANOVA with Bonferroni post-test and a 2-sided

α = 0.05. The 2-segmented analysis of regression slopes for MHH-TMC incidence was performed using Student t and 2-sided α = 0.05. In all cases, for a conservative estimated effect size of 0.1, the power (1 - β) of the study was ~ 0.9. Linear regression equations and Pearson *r* were calculated in a standard manner, not imposing any specific Y axis intersection. For all analyses and graphics, GraphPad Prism 7 was used.

Results

The annualized number of patients undergoing PCI during the study ranged from 803 to 1072. Before the intervention (Q1 of 2015) the post-PCI AKI adjusted incidences for p50, p90, and MHH-TMC were 6.4%, 3.1%, and 11.4%, respectively, thus representing a significantly higher rate at MHH-TMC in respect to both p50 and p90 ($P < 0.0001$).

During the study, the adjusted incidence of post-PCI AKI remained stable in the p50 and p90 centers, ranging from 5.7% to 6.4% and 2.6% to 3.2%; respectively. A regression analysis demonstrated a slight tendency to decay in the incidence of post-PCI AKI in p50 and p90 hospitals. The average decrease rate of incidence in p50 and p90 (represented by the slope of the regression equation) was 0.031 percentage points per month and 0.024 percentage points per month, respectively. That slight trend to decay was consistent over time in p50 and p90 ($r^2 = 0.72$ and $r^2 = 0.63$, respectively). Those decreasing rates were not significantly different between them ($P = 0.52$), suggesting a homogenous nation-wide tendency (Fig 1A).

Remarkably, MHH-TMC showed a different behavior during the study as compared with p50 and p90. The incidence of post-PCI AKI significantly decreased at a rate of 0.27 percentage points per month, that is: a decreasing rate about 1 order of magnitude higher than p50 and p90, reaching statistical significance ($P < 0.01$ in respect to both p50 and p90) (Fig 1B). That was also evidenced by the wide change of the incidence between Q2 of 2015 and Q4 2016: 11.4% and 6.7%, respectively. Importantly, the timeline regression analysis at MHH-TMC showed also a strong inverse correlation between incidence and time ($r^2 = 0.94$), thus demonstrating the consistency of the phenomenon. The significantly higher decreasing rate at MHH-TMC as compared with the relatively stable trend in p50 and p90 shows that it was a center-specific phenomenon and not a trivial reflex of a nation-wide tendency (Fig 1A and B).

That sustained decrease of post-PCI AKI incidence over time led MHH-TMC to reach a similar performance to that of p50 centers by Q2 of 2016, it is. At that time-point, the incidence in p50 and MHH-TMC was not significantly different (difference of 1.29 percentage points, $P = 0.13$).

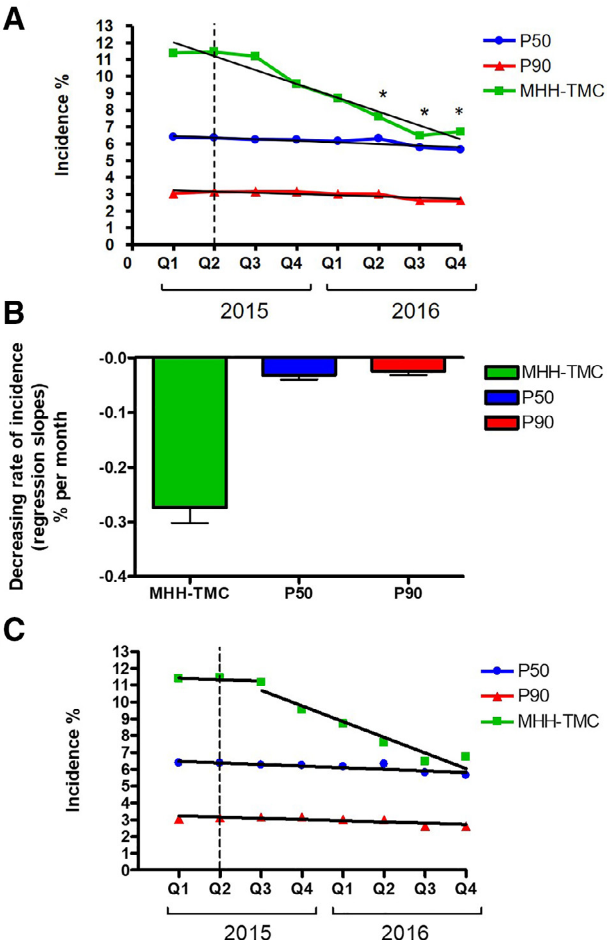

FIG 1. Annualized rates of incidence of acute kidney injury after percutaneous coronary intervention. (A) Timeline progression of post-PCI AKI incidence in MHH-TMC (green), p50 and p90 centers (blue and red respectively). Solid black lines represent the linear regression curves. (B) Bar graph representing the decreasing rate of post-PCI AKI incidence (slopes of the regression equations). (C) Time-segmented analysis shows the inflexion point of incidence at MHH-TMC in Q3 of 2015, shifting to a significantly stronger decreasing rate of post-PCI AKI incidence. *$P > 0.05$ MHH-TMC vs p50. Vertical dashed lines mark the implementation of the intervention at MHH-TMC. (Color version of figure is available online.)

MHH-TMC's performance remained comparable to p50 for the next 2 quarters until the end of the study in Q3 and Q4 of 2016 ($P = 0.40$ and $P = 0.17$) (Fig 1A). Although the incidence at MHH-TMC remained significantly higher than p90 hospitals ($P < 0.0001$ in all quarters), the difference between them decreased from 8.3 percentage points (Q1 of 2015) to 4.1

percentage points (Q4 of 2016). Furthermore, the expectation and goal of this study was to reach the performance of p50 as stated above.

Importantly, a time-segmented regression analysis demonstrated that during the period Q1-Q3 of 2015 (±1 quarter respect the intervention), MHH-TMC had a stable incidence of post-PCI AKI, with just a slight decreasing rate of 0.032 percentage points per month, not significantly different as compared with p50 and p90 (Fig 1C). The analysis of the period Q3 of 2015 to Q4 of 2016 (period starting 1 quarter after the intervention) showed a dramatic decrease of the incidence at a significantly higher rate of 0.31% per month. This fact strongly suggests that the improvement of the performance of MHH-TMC is attributable to the intervention implemented in Q2 of 2016 (Fig 1C).

Regarding the implementation of the plan, the compliance with the hydration protocol ranged from 45.5 to 84.2%, with an average of 64.8% during this time. Importantly, in the 71 cases of post-PCI AKI from Q1 to Q4 of 2016, compliance with the hydration protocol was only 30%, showing that compliance of the established plan was instrumental in the improvement of the performance of MHH-TMC.

Discussion

Current study shows that implementation of healthcare personnel education, coupled with an EMR-based PHP and a hydration task list, helped to significantly lower the incidence of post-PCI AKI in a large tertiary teaching center. This is evidenced by the constant decrease of the annualized post-PCI AKI rates in remarkable magnitude, significantly stronger than the national tendency, demonstrating a center-specific behavior. The critical time-point in which the incidence of post-PCI AKI started to decrease dramatically at MHH-TMC occurred 1 quarter after the intervention, whereas the incidence was stable before. No other remarkable PCI-related health-care policy modification was implemented during the study and the clinical and demographic characteristics of the patients did not change dramatically. Altogether, those facts provide evidence supporting that the health-care improvement implemented in this study was one of the; if not the main, driving forces in the performance improvement of MHH-TMC in terms of post-PCI.

Although these results are promising, the interpretation may have methodological limitations. First, given the hospital-wide nature of the intervention, there was no concurrent control arm. Instead, we used the 2 quarters prior to implementation as references. Second, we did not conduct refresher education module for new trainees/nurses taking care of these patients. Third, for patients with heart failure NYHA Classes III or IV, or Stage D, the hydration depended on the clinical judgment of their physician or midlevel provider, which may have not been uniform.

Post-PCI AKI is the third leading cause of AKI in hospitalized patients, and is associated with increased risk of mortality, myocardial infarction, and recurrent renal injury after discharge, and contributes to higher healthcare costs.[1,2] Considering this, our experience shows that the steps we took may be simple, implementable and economically efficient mechanisms to decrease rates of post-PCI AKI. Similar results have been seen with other programs based on healthcare personnel education, standardization of fluid orders, and a benchmark protocol.[5]

REFERENCES

1. Lafrance J-P, Miller DR. Acute kidney injury associates with increased long-term mortality. *J Am Soc Nephrol* 2010;21:345–52.
2. Valle JA, McCoy LA, Maddox TM, et al. Longitudinal risk of adverse events in patients with acute kidney injury after percutaneous intervention: insights from the National Cardiovascular Data Registry. *Circ Cardiovasc Interv* 2014;10:e004439.
3. Mehta RL, Kellum JA, Shah SV, et al. Acute Kidney Injury Network. Acute kidney injury network: report of an initiative to improve outcomes in acute kidney injury. *Crit Care* 2007;11:R31.
4. National Cardiovascular Registry. CathPCI: Acute Kidney Injury (risk-adjusted) Specifications and Testing Overview. Available from: https://www.ncdr.com/WebNCDR/docs/default-source/ncdr-general-documents/cathpci_kidney-injury-overview_comment-period.pdf?sfvrsn=2 [Accessed 7th July 2017].
5. Brown JR, Solomon RJ, Sarnak MJ, et al. Northern New England Cardiovascular Disease Study Group. Reducing contrast-induced acute kidney injury using regional multicenter quality improvement intervention. *Circ Cardiovasc Qual Outcomes* 2014;7:693-700.