Sitagliptin Augments Sympathetic Enhancement of the Renovascular Effects of Angiotensin II in Genetic Hypertension

Edwin K. Jackson, Zaichuan Mi

Abstract—Dipeptidyl peptidase IV converts neuropeptide Y1-36 (Y1-receptor agonist released from renal sympathetic nerves) to neuropeptide Y3-36 (selective Y2-receptor agonist). Previous studies suggest that Y1, but not Y2, receptors enhance renovascular responses to angiotensin II in kidneys from genetically-susceptible animals. Therefore, we hypothesized that inhibition of dipeptidyl peptidase IV with sitagliptin (antidiabetic drug) would augment the ability of exogenous and endogenous neuropeptide Y1-36 to enhance renal vascular responses to angiotensin II in kidneys from spontaneously hypertensive rats. This hypothesis was tested using 3 protocols in isolated perfused kidneys. Results from Protocol 1: Exogenous neuropeptide Y1-36 enhanced renovascular responses to angiotensin II. This effect of neuropeptide Y1-36 was blocked by BIBP3226 (selective Y1 receptor antagonist); Exogenous neuropeptide Y3-36 did not enhance renovascular responses to angiotensin II. Results from Protocol 2: Sitagliptin augmented the ability of exogenous neuropeptide Y1-36 to enhance renovascular responses to angiotensin II. This effect of sitagliptin was blocked by BIBP3226. Results from Protocol 3: Renal sympathetic nerve stimulation enhanced renovascular responses to angiotensin II; this enhancement was augmented by sitagliptin and abolished by BIBP3226. Neuropeptide Y1-36 via Y1 receptors enhances renovascular responses to angiotensin II in kidneys from genetically hypertensive animals. Sitagliptin, by blocking dipeptidyl peptidase IV, prevents metabolism of neuropeptide Y1-36 and thereby increases the effects of neuropeptide Y1-36 released from renal sympathetic nerves on Y1 receptors leading to augmentation of neuropeptide Y1-36–induced enhancement of the renovascular effects of angiotensin II. The renal effects of dipeptidyl peptidase IV inhibitors in hypertensive diabetic patients merit a closer examination. (Hypertension. 2008;51:1637-1642.)

Key Words: neuropeptide Y ■ CD26 ■ receptors ■ neuropeptide Y ■ rats ■ inbred SHR ■ sympathetic nervous system ■ kidney ■ renal circulation

Our previously published results indicate that activation of renovascular Y1 receptors (Y1Rs) markedly enhances renovascular responses to physiological levels of angiotensin II (Ang II) in kidneys of spontaneously hypertensive rats (SHR).1 In contrast, kidneys from normotensive Wistar-Kyoto rats (WKY) are resistant to this interaction.1 Our studies also show that unlike Y1Rs, renovascular Y2 receptors (Y2Rs) exert little effect on Ang II–induced renovascular responses in kidneys from either SHR or WKY.1 Although we do not know precisely why SHR, but not WKY, kidneys are susceptible to Y2 receptor agonist activity,1 we have shown that endogenous agonists of Y2Rs exert little effect on Ang II–induced renovascular responses in kidneys from either SHR or WKY.1

In this regard, there are 2 endogenous agonists of Y2Rs that would be presented to the kidney microcirculation, ie, peptide YY1,36 (PYY1,36) and neuropeptide Y1,36 (NPY1,36). Both are pancreatic polypeptide-fold peptides. A fatty meal releases PYY1,36 into the systemic circulation from endocrine L-cells in the small bowel, colon, and rectum producing physiologically active levels of PYY1,36 in plasma that are 500% to 1000% above basal circulating levels,2–8 and this circulating PYY1,36 would be delivered promptly to the renal microcirculation via the blood stream (humoral Y1R-agonist input to kidney microcirculation). Renal sympathetic nerves release NPY1,36 in response to central nervous system–mediated activation of the renal sympathetic nerves (neural Y1R-agonist input to kidney microcirculation), resulting in high local levels of NPY1,36 in sympathetically-innervated renal microvessels during renal sympathetic activation.9 Because both PYY1,36 and NPY1,36 are potent Y1R agonists,10,11 physiological processes that increase PYY1,36 release from the gut, NPY1,36 release from renal sympathetic nerves, or both simultaneously would activate Y1Rs in the renal microcirculation, which in genetically-susceptible kidneys would enhance Ang II–induced renal vasoconstriction.
It is conceivable, however, that renal dipeptidyl peptidase IV (DPP IV, also called CD26) limits stimulation of renal Y1Rs by physiological processes that increase the exposure of the renal microcirculation to PYY and NPY. DPP IV is an ecto-enzyme that is anchored to the cell surface and converts PYY to PYY1-36 and NPY1-36. DPP IV is a determinant of the extent to which PYY and NPY enhance renovascular responses to Ang II in genetically-susceptible kidneys.

In support of this concept, our recently published study demonstrates that in SHR kidneys: (1) PYY enhances renovascular responses to Ang II, whereas PYY1-36 has little effect in this regard; (2) P32/98 (DPP IV inhibitor) augments the ability of PYY1-36 to enhance renovascular responses to Ang II; (3) DPP IV is expressed in preglomerular microvessels and glomeruli; (4) kidneys metabolize arterial PYY and NPY1-36 to PYY1-36 and NPY1-36 via a mechanism blocked by P32/98; and (5) freshly isolated preglomerular microvessels and glomeruli convert PYY1-36 to PYY1-36 and this conversion is inhibited by P32/98. These results confirm that DPP IV is expressed in the renal microcirculation and that inhibition of this ecto-enzyme causes arterial PYY1-36 to more effectively enhance Ang II–induced renal vasoconstriction in genetically-susceptible kidneys.

Although the aforementioned study supports the hypothesis that renal DPP IV importantly modifies the effects of humoral Y1R agonist input to the kidney microcirculation, this study does not address whether renal DPP IV significantly influences the effects of neural Y1R agonist input to the kidney. This is an important unanswered question because previously published results indicate that renal sympathetic nerve stimulation enhances renovascular responses to Ang II in the SHR, but not WKY, kidneys via a Y1R mechanism. Therefore, one aspect of the present study was to determine whether inhibition of DPP IV alters the ability of exogenous NPY1-36 and endogenous NPY1-36 (ie, that released from renal sympathetic nerves in response to periarterial renal nerve stimulation) to enhance renovascular responses to Ang II.

Another important unanswered question is whether clinically available DPP IV inhibitors affect the ability of exogenous and endogenous Y1R agonists to enhance renovascular responses to Ang II. P32/98 is a DPP IV inhibitor that is available from chemical supply companies but is not used clinically, nor is P32/98 as potent as clinically used DPP IV inhibitors. Another aspect of the present study was to examine the effects of sitagliptin (Januvia), a potent, selective, and recently FDA-approved and marketed DPP IV inhibitor, on the interaction between exogenous and endogenous NPY1-36 on Ang II–induced renal vasoconstriction in kidneys from genetically hypertensive rats.

Methods

Animals

Studies used adult (14 to 16 weeks-of-age) male SHR obtained from Taconic Farms (Germantown, NY). The Institutional Animal Care and Use Committee approved all procedures. The investigation conforms to the Guide for the Care and Use of Laboratory Animals published by the US National Institutes of Health (NIH Publication No. 85 to 23, revised 1996).

Isolated, Perfused Kidney Preparation

SHR were anesthetized with Inactin (90 mg/kg, IP, Sigma-Aldrich), and the left kidney was isolated and perfused with Tyrode solution using a Hugo Sachs Elektronik-Harvard Apparatus GmbH (March-Hugstetten) kidney perfusion system as previously described. Briefly, all branches of the left renal artery and vein were ligated. A polyethylene-50 cannula was placed into the left renal artery, and a polyethylene-90 cannula was placed into the left renal vein. The left kidney was removed, attached to the perfusion system, and allowed to stabilize for an hour before the experimental protocol. Kidneys were perfused (single pass mode) at a constant flow (5 mL/min), and perfusion pressure was monitored with a pressure transducer.

Protocol 1

Kidneys were isolated from adult SHR and perfused in vitro as described above. After a 1-hour stabilization period, renovascular responses (ie, changes in perfusion-pressure) to 0.3 nmol/L of Ang II were assessed by infusing Ang II into the perfusate for 10 minutes and noting the difference between the perfusion pressure just before the Ang II infusion compared to the perfusion pressure at the end of the Ang II infusion. The infusion of Ang II was stopped, and 10 minutes later the kidneys were exposed to NPY1-36 or NPY3-36 (6 nmol/L) for 20 minutes. Ten minutes into the treatments with either NPY1-36 or NPY3-36, Ang II was infused once again for 10 minutes to obtain another renovascular response to Ang II, but this time in the presence of either NPY1-36 or NPY3-36. Some kidneys were treated with BIBP3226 (1 µmol/L), a highly selective Y1R antagonist, beginning 20 minutes before the first renovascular response to Ang II and continuing until the end of the protocol. The effect of NPY1-36 or NPY3-36 on the renovascular response to Ang II was calculated by subtracting the renovascular response to Ang II before treatment with either NPY1-36 or NPY3-36 from the renovascular response to Ang II after treatment with either NPY1-36 or NPY3-36. Ang II, NPY1-36, NPY3-36, and BIBP3226 were obtained from Sigma-Aldrich.

Protocol 2

Kidneys were isolated from adult SHR and perfused in vitro as described above. After a 1-hour stabilization period, the renovascular response (as defined above) to Ang II (0.1 nmol/L) was assessed by infusing Ang II into the perfusate for 10 minutes. The infusion of Ang II was stopped, the kidney was exposed to 0.1 nmol/L of NPY1-36, and 10 minutes into the treatment with 0.1 nmol/L of NPY1-36, the renovascular response to Ang II was again obtained by infusing Ang II (0.1 nmol/L) for 10 minutes. The infusion of Ang II was again stopped, and the concentration of NPY1-36 was increased to 0.3 nmol/L for 20 minutes, and 10 minutes into this higher concentration of NPY1-36, the renovascular response to Ang II (0.1 nmol/L) was again obtained by infusing Ang II (0.1 nmol/L) for 10 minutes. This procedure was repeated as the concentration of NPY1-36 was increased to 1 nmol/L and finally to 3 nmol/L. Some kidneys were pretreated for 10 minutes before the first response to Ang II with either sitagliptin (1 µmol/L) or sitagliptin + BIBP3226 (1 µmol/L), and these treatments were maintained throughout the experiment. The fold-increase in the renovascular response to Ang II was calculated by dividing the renovascular response before administering NPY1-36 into the renovascular response to Ang II in the presence of each concentration of NPY1-36.

Protocol 3

Kidneys were isolated from adult SHR and perfused in vitro as described above. Care was taken not to damage the periarterial renal sympathetic nerves during isolation by leaving as much tissue as possible around the artery and avoiding trauma to the nerves. Immediately after initiating perfusion of the kidney, a platinum bipolar electrode was positioned around the renal artery close to the
kidney for renal nerve stimulation, and the electrode was connected to a Grass stimulator (model SD9E; Grass Instruments). The tissues around the electrode were kept moist with Tyrode solution. After a 1-hour stabilization period, prazosin (30 nmol/L) was infused into the renal artery to block α1-adrenoceptors so that renal nerve stimulation would not cause direct vasoconstriction and would not increase basal renovascular tone.1,4 Some kidneys also were pretreated with sitagliptin (1 μmol/L). The infusions of prazosin or prazosin plus sitagliptin were continued for the duration of the experiment. Ten minutes after initiating the infusions of prazosin or prazosin plus sitagliptin, a sham perirenal renal nerve stimulation was performed by going through the motions of activating the stimulator while not actually activating the stimulator. Two minutes into the sham renal nerve stimulation, Ang II (0.1 nmol/L) was infused into the renal artery for 7 minutes to obtain a renovascular response to Ang II (as defined above). This first renovascular response to Ang II was designated the period 1 response, which was a basal/control response. At the end of the Ang II infusion, kidneys were allowed to recover for 10 minutes and then were subjected to renal nerve stimulation (biphasic, 5 Hz, 1-ms pulse duration, 35 V) for 9 minutes. Two minutes into the renal nerve stimulation, Ang II (0.1 nmol/L) was infused once again for 7 minutes to obtain another renovascular response to Ang II. This second renovascular response to Ang II was designated the period 2 response, which was a response to Ang II in the presence of renal nerve stimulation. At this point, both the Ang II infusion and the renal nerve stimulation were discontinued, and an infusion of BIBP3226 (1 μmol/L) was initiated and continued until the end of the protocol. After a 20-minute stabilization period, the kidneys were once again subjected to renal nerve stimulation (biphasic, 5 Hz, 1-ms pulse duration, 35 V) for 9 minutes. Two minutes into the renal nerve stimulation, Ang II (0.1 nmol/L) was infused again for 7 minutes to obtain a third renovascular response to Ang II. This third response to Ang II was designated the period 3 response, which was a response to Ang II in the presence of renal nerve stimulation plus BIBP3226.

**Extraction of Sitagliptin**

Sitagliptin is not available from chemical supply companies. However, because sitagliptin phosphate monohydrate is highly water soluble, we purchased Januvia tablets containing 100 mg of sitagliptin phosphate monohydrate from the University of Pittsburgh Medical Center hospital pharmacy and dissolved these tablets in Tyrode solution. In this regard, we added a 100-mg Januvia tablet to 10 mL of Tyrode solution and placed this preparation in the refrigerator for 1 hour to allow tablet dissolution to occur. The preparation was then vortexed at room temperature and then centrifuged to remove any particulates. An appropriate volume of this preparation (based on the labeled amount of sitagliptin in the tablet) was then diluted in Tyrode solution to give the desired final concentration of sitagliptin in the perfusate. The solution was then tested by ion-trap mass spectrometry. The mass spectrum of the extract was characterized by a single peak at 408 m/z corresponding to protonated sitagliptin ([M+H]+ 408).

**Statistical Analysis**

Data were analyzed by 1-factor analysis of variance, repeated measures 2-factor analysis of variance, Fisher Least Significant Difference (LSD) test, or Mann-Whitney U test as appropriate. The criterion of significance was P < 0.05. All data are presented as means ± SEM.

**Results**

**Protocol 1**

As shown in Figure 1, the Ang II–induced change in renal perfusion pressure was enhanced by 47 ± 7 mm Hg (n = 7) by NPY1-36 (6 nmol/L). Unlike NPY1-36, NPY 3-36 (n = 7) had little effect on Ang II–induced changes in perfusion pressure (Figure 1). Moreover, the ability of NPY1-36 to potentiate renovascular responses to Ang II was blocked by pretreating the kidneys for 20 minutes with BIBP3226 (1 μmol/L; n = 6; Figure 1), a highly selective Y1-receptor blocker.10

![Figure 1. Bar graph shows enhancement of angiotensin II (Ang II)–induced changes in renal perfusion pressure by neuropeptide Y1-36 (NPY1-36; 6 nmol/L), without and with BIBP3226 (BIBP; 1 μmol/L) and by neuropeptide Y3-36 (NPY3-36; 6 nmol/L). The effect of NPY1-36 or NPY3-36 on the renovascular response to Ang II was calculated by subtracting the renovascular response to Ang II before treatment with either NPY1-36 or NPY3-36 from the renovascular response to Ang II after treatment with either NPY1-36 or NPY3-36. The concentration of Ang II was 0.3 nmol/L. Basal perfusion pressure (48 ± 2 mm Hg) was similar among the 3 groups and was not affected by NPY1-36, NPY3-36, or BIBP3226. The basal response to Ang II (before treatments) was similar among the 3 groups and was 31 ± 3 mm Hg. The probability value is from 1-factor analysis of variance. *P < 0.05 vs other groups (Fisher LSD test). Values represent means ± SEM for the indicated sample size.](http://hyper.ahajournals.org/lookup/suppl/doi:10.1161/01.HYP.0000564356.26396.a3/-/media/ahajournals/hypertension/journals/1639/jacksonmi1639F1.ashx?width=480&height=408)
Ang II–induced renovascular responses. Also, in both nonsitagliptin-treated control kidneys and in sitagliptin-treated kidneys BIBP3226 blocked all effects of renal nerve stimulation on Ang II–induced renovascular responses. Notably, the fold-enhancement of Ang II–induced renovascular responses was significantly (P=0.0227) greater in sitagliptin-treated versus nonsitagliptin-treated kidneys (3.60-fold versus 1.51-fold).

Discussion

The results from the first protocol of the present study demonstrate that a high concentration of exogenous NPY1-36 markedly enhances renovascular responses to Ang II in SHR kidneys. This finding supports the concept that if endogenous concentrations of NPY1-36 achieve a high enough level, endogenous NPY1-36 also should enhance renovascular responses to Ang II in kidneys from genetically-susceptible kidneys. Importantly, BIBP3226, a selective Y1R antagonist, abrogates the effects of a high concentration of exogenous NPY1-36 on renovascular responses to Ang II. This finding implies that the effect of NPY1-36 on renovascular responses to Ang II is mediated by activation of Y1Rs and not by other Y-receptor subtypes. Consistent with this interpretation, a high concentration of exogenous NPY1-36, a peptide that selectively activates Y1Rs and is inactive at Y1Rs, is not efficacious with regard to enhancing Ang II–induced renal vasoconstriction. Because DPP IV metabolizes NPY1-36 to NPY3-36,2 this latter finding implies that renovascular DPP IV has the potential to minimize the renovascular impact of endogenous NPY1-36 in genetically-susceptible kidneys by converting the efficacious NPY1-36 to the nonefficacious NPY3-36.

The results from the second protocol of the present study are consistent with the hypothesis that renovascular DPP IV minimizes the renovascular impact of endogenous NPY1-36 in genetically-susceptible kidneys. In this regard, we observe that very low concentrations of exogenous NPY1-36 have little effect on renovascular responses to Ang II in genetically-susceptible kidneys. In contrast, when very low concentrations of exogenous NPY1-36 are administered to kidneys pretreated with sitagliptin, a potent and clinically useful DPP

Figure 3. Bar graph shows the renovascular response to angiotensin II (Ang II) in the absence of renal nerve stimulation and BIBP3226 (Basal), during perirterial renal nerve stimulation (RNS; 5 Hz, 1-ms pulse duration, 35 V), and during RNS in the presence of BIBP3226 (RNS + BIBP; 1 µmol/L). In the left panel, kidneys were not pretreated with sitagliptin, whereas in the right panel, kidneys were pretreated with sitagliptin (1 µmol/L) throughout the experiment. The concentration of Ang II was 0.1 nmol/L. Basal perfusion pressure in the presence of prazosin (42±2 mm Hg) was similar among the 3 groups and was not affected by RNS or BIBP3226. The probability values are from 1-factor analysis of variance. *P<0.05 vs other groups (Fisher LSD test). Values represent means±SEM for the indicated sample size.
IV inhibitor, even these minute concentrations of exogenous NPY1-36 enhance renovascular responses to Ang II. This finding strongly suggests that renovascular DPP IV inactivates NPY1-36 so that low concentrations cannot enhance the renovascular effects of Ang II; however, when DPP IV is inhibited, this inactivation is impaired and so even low concentrations of NPY1-36 potentiate renovascular responses to Ang II.

Although the first and second protocols are consistent with the concept that endogenous NPY1-36 may regulate renovascular responses to Ang II in genetically-susceptible kidneys, these experiments do not directly address this critical issue. As discussed above, the main source of renal NPY1-36 is neural, i.e., NPY1-36 is a cotransmitter in renal sympathetic nerve varicosities. Therefore, a straightforward approach to test the role of endogenous NPY1-36 with regard to its interaction with Ang II is to examine renovascular responses to Ang II in the absence and presence of renal sympathetic nerve stimulation. However, renal nerve stimulation normally increases renovascular tone, and increases in renovascular tone would be expected to enhance responses to any vasoconstrictor. Therefore, such experiments would be impossible to interpret. However, an experimental design around the confounding variable of changes in basal renovascular tone is released on nerve stimulation but the coreleased norepinephrine cannot increase basal renovascular tone.

Protocol 3 demonstrates that renal nerve stimulation in the presence of prazosin does indeed enhance the renovascular response to Ang II without changing basal renovascular tone. Moreover, this protocol shows that the effect of renal nerve stimulation on the renovascular response to Ang II is entirely blocked by BIBP3226. Thus it is clear that Y1Rs mediate the effect of renal nerve stimulation on renovascular responses to Ang II, a finding consistent with our previously published results. Because NPY1-36 is the only known Y1R agonist released from renal sympathetic nerves, it is nearly certain that the enhancement of renovascular responses to Ang II by renal nerve stimulation is mediated entirely by endogenous NPY1-36 activating Y1Rs.

As mentioned above, an implication of protocols 1 and 2 is that renovascular DPP IV inactivates NPY1-36 so that low concentrations cannot enhance the renovascular effects of Ang II; however, when DPP IV is inhibited, this inactivation is impaired and so even low concentrations of NPY1-36 potentiate renovascular responses to Ang II. If this conclusion can be applied to endogenous NPY1-36, then sitagliptin, a DPP IV inhibitor, should augment the effects of renal nerve stimulation on renovascular responses to Ang II. Importantly, the results of protocol 3 are entirely consistent with this hypothesis, i.e., renal nerve stimulation enhances renovascular responses to Ang II more so in kidneys treated with sitagliptin compared with kidneys not treated with sitagliptin. The fact that BIBP3226 blocks the ability of sitagliptin to augment the interaction between renal nerve stimulation and Ang II is entirely consistent with the effects of sitagliptin being mediated by reducing metabolism of endogenous NPY1-36.

The present study does not examine the interaction between NPY1-36 and Ang II in WKY rats because such an interaction cannot be demonstrated. In this regard, our previous studies show that activation of Y1Rs, even with high concentrations of potent Y1R agonists such as (Leu31,Pro34)-NPY or PY1Y1-36, has little or no ability to enhance renovascular responses to Ang II in WKY kidneys. Our previous results also demonstrate that renal nerve stimulation does not enhance renovascular responses to Ang II in WKY kidneys. Thus, with respect to the interaction between Ang II and NPY1-36, it is a moot point as to whether DPP IV regulates the levels of NPY1-36 in WKY kidneys because the peptide cannot significantly alter Ang II–induced renal vasoconstriction regardless of whether or not it is metabolized by DPP IV. The ability of Y1Rs to enhance renovascular responses in SHR kidneys, but not WKY kidneys, is attributable to the fact that Y1Rs signal via the Gi pathway. In this regard, activation of the Gi pathway enhances renovascular responses to Ang II in SHR, but not WKY, kidneys. Why this is the case is presently unknown, but it is under investigation. Nonetheless, whether renovascular or glomerular DPP IV expression is increased in hypertension is an interesting and important question that deserves investigation because DPP IV has many substrates and alters the levels of a large array of polypeptides.

Perspectives
The FDA recently approved sitagliptin, a potent inhibitor of DPP IV, for the treatment of type 2 diabetes, and other similar compounds are in the development and approval pipeline. Given the epidemic of type 2 diabetes and the emerging controversy regarding the safety of PPARγ agonists (the thiazolidinediones) in type 2 diabetics, it is likely that DPP IV inhibitors will become widely used in type 2 diabetics, many of whom will have hypertension as a comorbidity. The results of the present study support the hypothesis that DPP IV inhibitors, in the appropriate genetic setting, may augment the ability of endogenously released NPY1-36 to enhance renovascular responses to Ang II. In this highly vulnerable patient population, this could impair renal function, increase arterial blood pressure, and inadvertently lead to an increased risk of stroke and myocardial infarction. Counteracting this possible adverse effect of DPP IV inhibitors on renal function is the fact that, as shown by Girardi and colleagues, DPP IV forms a physical complex with the sodium hydrogen exchanger type 3 (NHE3) in the proximal tubular brush border so that inhibition of DPP IV leads to a reduction in NHE3-mediated transport. Thus, the renal effects of DPP IV inhibitors in hypertensive diabetic patients will be complicated and perhaps strongly dependent on the genetic predisposition of the patient. Certainly, the renal effects of DPP IV inhibitors in various patient populations merit a closer examination. In the meanwhile, it may be prudent to consider the concomitant use of an angiotensin receptor blocker or renin inhibitor (but perhaps not an angiotensin converting enzyme inhibitor which possibly could increase the risk of angioedema in patients treated with DPP IV inhibitors) in type 2 diabetics treated with DPP IV inhibitors until this issue is resolved.
Sources of Funding
This work was supported by NIH grants HL69846 and DK068575.

Disclosures
None.

References
Sitagliptin Augments Sympathetic Enhancement of the Renovascular Effects of Angiotensin II in Genetic Hypertension
Edwin K. Jackson and Zaichuan Mi

Hypertension. 2008;51:1637-1642; originally published online April 28, 2008;
doi: 10.1161/HYPERTENSIONAHA.108.112532
Hypertension is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2008 American Heart Association, Inc. All rights reserved.
Print ISSN: 0194-911X. Online ISSN: 1524-4563

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/51/6/1637

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Hypertension can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Hypertension is online at:
http://hyper.ahajournals.org//subscriptions/