



BP MEASUREMENT AND VARIABILITY IN CKD

**George S. Stergiou
Konstantinos Kyriakoulis**

**Hypertension Center STRIDE-7
Third University Department of Medicine
Sotiria Hospital, Athens Greece**

BPM and BPV in CKD

BPM

Systematic PubMed search

Articles

- White-coat and Masked HTN 9
- Nocturnal BP and Dip 14
- ABPM/HBPM and TOD 15
- ABPM/HBPM and Outcome 22
- Oscillometric BPM 6

BPV

- VVV, ABPV, HBPV and TOD 9
- VVV, ABPV, HBPV and Outcome 8

NOT DISCUSSED

BPM

- **ABP/HBP in non-CKD**
- **BP goals of treatment**

BPV

Key Study Aspects

- 1. What population**
- 2. What design**
- 3. Which BPM method**
- 4. What endpoints**

BPM and BPV in CKD

BPM

Articles

- | | | |
|---|----------------------------------|-----------|
| ☐ | White-coat and Masked HTN | 9 |
| ☐ | Nocturnal BP and Dip | 14 |
| ☐ | ABPM/HBPM and TOD | 15 |
| ☐ | ABPM/HBPM and Outcome | 22 |
| ☐ | Oscillometric BPM | 6 |

BPV

- | | | |
|---|------------------------------------|----------|
| ☐ | VVV, ABPV, HBPV and TOD | 9 |
| ☐ | VVV, ABPV, HBPV and Outcome | 8 |

White-Coat/Masked HTN in CKD (9)

Study	Year	Country	Design	N	OBP	ABP/ HBP	WC (%)	MH (%)
<i>Oh et al.</i>	2017	S Korea	cross-sectional	387	Ausc. 2	ABP	10	27
<i>Cha et al.</i>	2017	S Korea	prospective, observ cohort	378	Osc. 2	ABP	3	50
<i>Agarwal et al.</i>	2016	USA	prospective, observ cohort	333	Osc. 9	ABP/ HBP	-	A33 H51
<i>Gorostidi et al.</i>	2013	Spain	cross-sectional	5,693	Osc. 2	ABP	29	7
<i>Shafi et al.</i>	2012	USA	cross-sectional	156	Osc - 2	ABP	30	6
<i>Minutolo et al.</i>	2011	Italy	prospective, observ cohort	459	Ausc. 6	ABP	41	-
<i>Kanno et al.</i>	2010	Japan, Ohasama	cross-sectional	164	Osc. 2	ABP	19	23
<i>Pogue et al.</i>	2009	USA, AASK	prospective, observ cohort	619	Ausc. 2	ABP	2	43
<i>Terawaki et al.</i>	2008	Japan, Ohasama	cross-sectional	751	Osc. 2	HBP	15	14

BPM and BPV in CKD

BPM

Articles

- | | | |
|---|---------------------------|----|
| ○ | White-coat and Masked HTN | 9 |
| ○ | Nocturnal BP and Dip | 14 |
| ○ | ABPM/HBPM and TOD | 15 |
| ○ | ABPM/HBPM and Outcome | 22 |
| ○ | Oscillometric BPM | 6 |

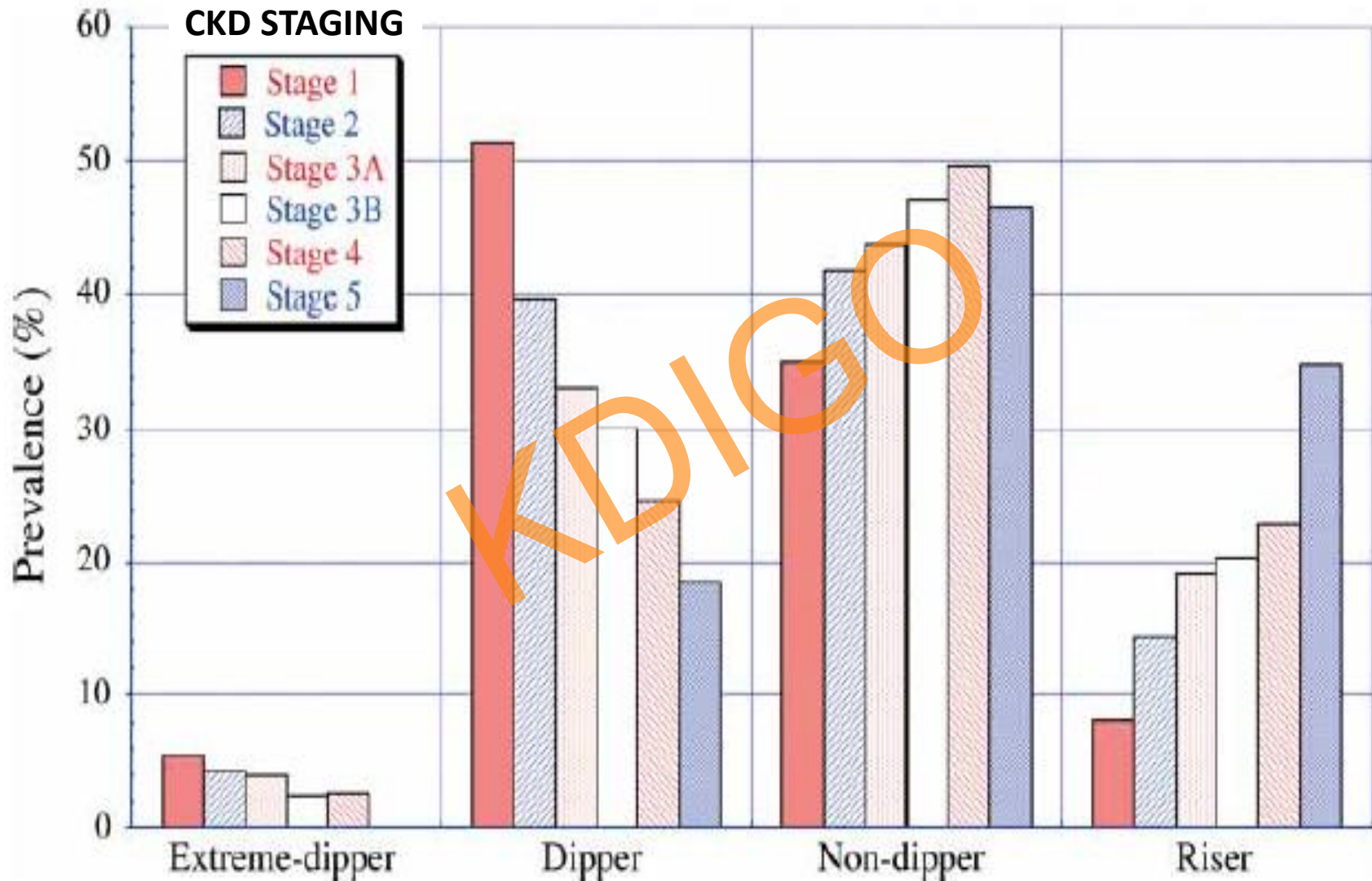
BPV

- | | | |
|---|-----------------------------|---|
| ○ | VVV, ABPV, HBPV and TOD | 9 |
| ○ | VVV, ABPV, HBPV and Outcome | 8 |

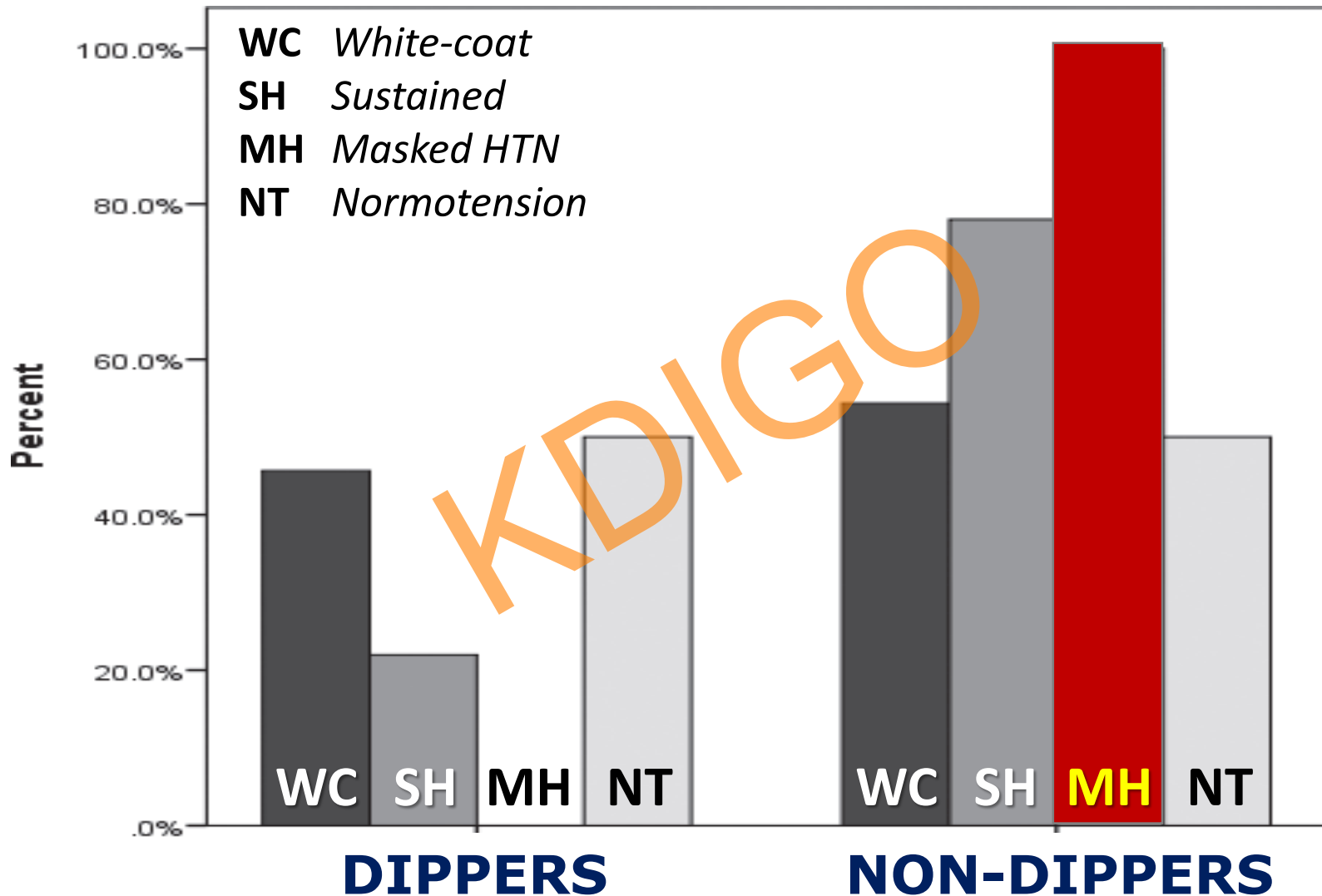
Nocturnal BP Dip in CKD (14)

Study	Year	Country	Design	N	Extr Dip (%)	Dip (%)	Non-Dip (%)	Rev-Dip (%)	67%
<i>Oh et al.</i>	2017	S Korea	Cross-sectional	387	6	38	42	14	56
<i>Cha et al.</i>	2017	S Korea	Prospective, observ cohort	378	11	22	31	35	66
<i>Che et al.</i>	2017	China	Cross-sectional	257				75*	75
<i>Wang et al.</i>	2016	China	Prospective, observ cohort	588	4	35	43	18	61
<i>Hurtado et al.</i>	2016	Spain	Cross-sectional	4,870	39		41	19	60
<i>Fedecostante et al.</i>	2014	Italy	Cross-sectional	270		28		73*	73
<i>Wang et al.</i>	2013	China	Cross-sectional	540		36	42	22	64
<i>Rahman et al.</i>	2013	USA AASK	Prospective	147		24	46	30	76
<i>Mojón et al.</i>	2012	Spain	Cross-sectional	3,227		39	43	18	61
<i>Crespo et al.</i>	2012	Spain	Cross-sectional	2,659		10	68	21	89
<i>Minutolo et al.</i>	2011	Italy	Prospective, observ cohort	436	11	33	43	14	57
<i>Pogue et al.</i>	2009	USA AASK	Prospective, observ cohort	619	20		41	39	80
<i>Jacob et al.</i>	2004	Germany	Prospective, observ cohort	95	39			61	61
<i>Timio et al.</i>	1995	Italy	Prospective, observ cohort	48	42			58	58

Dipping Pattern and CKD Staging



Non-Dipping and Masked HTN



BPM and BPV in CKD

BPM

Articles

- | | | |
|---|---------------------------|----|
| ○ | White-coat and Masked HTN | 9 |
| ○ | Nocturnal BP and Dip | 14 |
| ○ | ABPM/HBPM and TOD | 15 |
| ○ | ABPM/HBPM and Outcome | 22 |
| ○ | Oscillometric BPM | 6 |

BPV

- | | | |
|---|-----------------------------|---|
| ○ | VVV, ABPV, HBPV and TOD | 9 |
| ○ | VVV, ABPV, HBPV and Outcome | 8 |

BPM in CKD and TOD (15)

Author	N	Months	Country	Subjects	BPM	Endpoint	ASSOCIATIONS
Agarwal 2008	133	Cross sectional	USA	Dialysis	ABP, HBP	LVH	HBP, ABP SBP with LVH
Agarwal 2006	140	Cross sectional	USA	Dialysis	ABP, HBP	LVH	HBP, ABP SBP with LVH
Zoccali 1999	64	Cross sectional	Italy	Dialysis	ABP	LVH	ABP not with LVH
Che 2017	257	Cross sectional	China	CKD	ABP dip	LVH	Non-dippers with LVH
Cha 2017	378	12	S Korea	CKD	ABP dip	LVH, eGFR, UPrt	Non-dippers with proteinuria
Agarwal 2016	255	48	USA	CKD	CBP, ABP	PWV	CBP and dayABP with PWV
Agarwal 2016	274	48	USA	CKD	CBP, ABP	LVH	CBP and ABP with LVH
Fedecostante 2014	270	Cross sectional	Italy	CKD	ABP	LVH	ABP with LVH
Wang 2013	540	Cross sectional	China	CKD	ABP dip	LVH, IMT	Reverse-dippers with LVH, IMT
Agarwal 2009	103	Cross sectional	USA	CKD	ABP	eGFR, UPrt	Non-dippers with albuminuria
Jacob 2004	95	36	Germany	CKD	ABP	SCr	ABP S with CKD progression
Suzuki 2002	113	36	Japan	CKD	CBP, HBP	eGFR	CBP and HBP with ↓ eGFR
Rave 1999	77	74	Germany	CKD DM1	CBP, HBP	eGFR	HBP better than CBP with eGFR
Timio 1995	48	36	Italy	CKD	ABP dip	CrCl	Non-dippers with CrCl decline
Palmas 2006	918	24	USA	DM II	ABP	ACR	Ambulatory PP with ↑ ACR

BPM and BPV in CKD

BPM

Articles

- | | | |
|---|---------------------------|----|
| ○ | White-coat and Masked HTN | 9 |
| ○ | Nocturnal BP and Dip | 14 |
| ○ | ABPM/HBPM and TOD | 15 |
| ○ | ABPM/HBPM and Outcome | 22 |
| ○ | Oscillometric BPM | 6 |

BPV

- | | | |
|---|-----------------------------|---|
| ○ | VVV, ABPV, HBPV and TOD | 9 |
| ○ | VVV, ABPV, HBPV and Outcome | 8 |

ABP HBP and Outcome in CKD (22)

Study	N	Months	Country	Subjects	BPM Method	Endpoints
Amar J et al. 2000	57	34	France	Hemodialysis	ABP	CV mortality
Tripepi G, et al. 2005	168	38	Italy	Hemodialysis	ABP, Dip	CV-Total mortality
Alborzi P, et al. 2007	150	24	USA	Hemodialysis	HBP	CV-Total mortality
Agarwal R, et al. 2008	133	24	USA	Hemodialysis	HBP, ABP	Total mortality
Agarwal R. 2010	326	32	USA	Hemodialysis	HBP, ABP	Total mortality
Agarwal R, et al. 2006	217	41	USA	CKD	HBP, ABP	CV endpoints
Agarwal R, et al. 2006	217	41	USA	CKD	ABP	Total mortality, ESRD
Agarwal R, et al. 2006	217	41	USA	CKD	HBP	Renal endpoints
Okada et al. 2008	137	32	Japan	CKD	HBP	Renal endpoints
Agarwal R, et al. 2009	179	104	USA	CKD	ABP dip	Total mortality, CKD
Okada et al. 2009	79	39	Japan	CKD elderly	HBP	Renal endpoints
Redon et al. 2010	79	44	Spain	CKD	ABP	Total mortality, ESRD
Minutolo R, et al. 2011	436	50	Italy	CKD	ABP day-night	CV events, Renal death
McMullan C, et al. 2015	394	Cross-sect	USA	CKD Afr.Am.	ABP surge	CV endpoints
Wang C, et al. 2016	588	35	China	CKD	ABP dip	CV-Total mortality, Renal endpoints
Li Y, et al. 2017	588	35	China	CKD	ABP night	CV-Total mortality, Renal endpoints
Cha et al. 2017	378	12	Korea	CKD	ABP dip	CV endpoints
Turak O, et al. 2015	622	41	Turkey	HTN	ABP surge	Renal endpoints
Kanno A, et al. 2013	843	100	Japan	General population	ABP	Total mortality, CKD
McMullan C, et al. 2015	603	97	USA	Gen-Popul. Afr.Am.	ABP dip	Renal endpoints
Terawaki H, et al. 2008	1,365	Cross-sect	Japan	General population	HBP	Renal endpoints
Kanno A, et al. 2010	1,023	Cross-sect	Japan	General population	HBP	Renal endpoints

**ABP/HBP
IN CKD**

CVD ENDPOINTS

BPM Location Not Quantity

Predicts Death in Hemodialysis Patients

<i>Total and CV Death</i>	systolic blood pressure			diastolic blood pressure		
	HR per 10 mm Hg	95% CI	p	HR per 5 mm Hg	95% CI	p
→ Routine dialysis unit						
Pre-dialysis	1.05	0.92–1.20	0.5	1.02	0.91–1.15	0.697
Post-dialysis	1.17	1–1.37	0.043	1.06	0.93–1.21	0.398
→ * Standardized dialysis unit						
Pre-dialysis	1.13	0.99–1.30	0.073	1.05	0.94–1.18	0.407
Post-dialysis	1.16	1.01–1.33	0.035	1.02	0.91–1.15	0.69
→ Home	1.17	1.02–1.35	0.026	1.15	1.02–1.30	0.022
→ Ambulatory	1.22	1.07–1.38	0.002	1.18	1.05–1.31	0.005

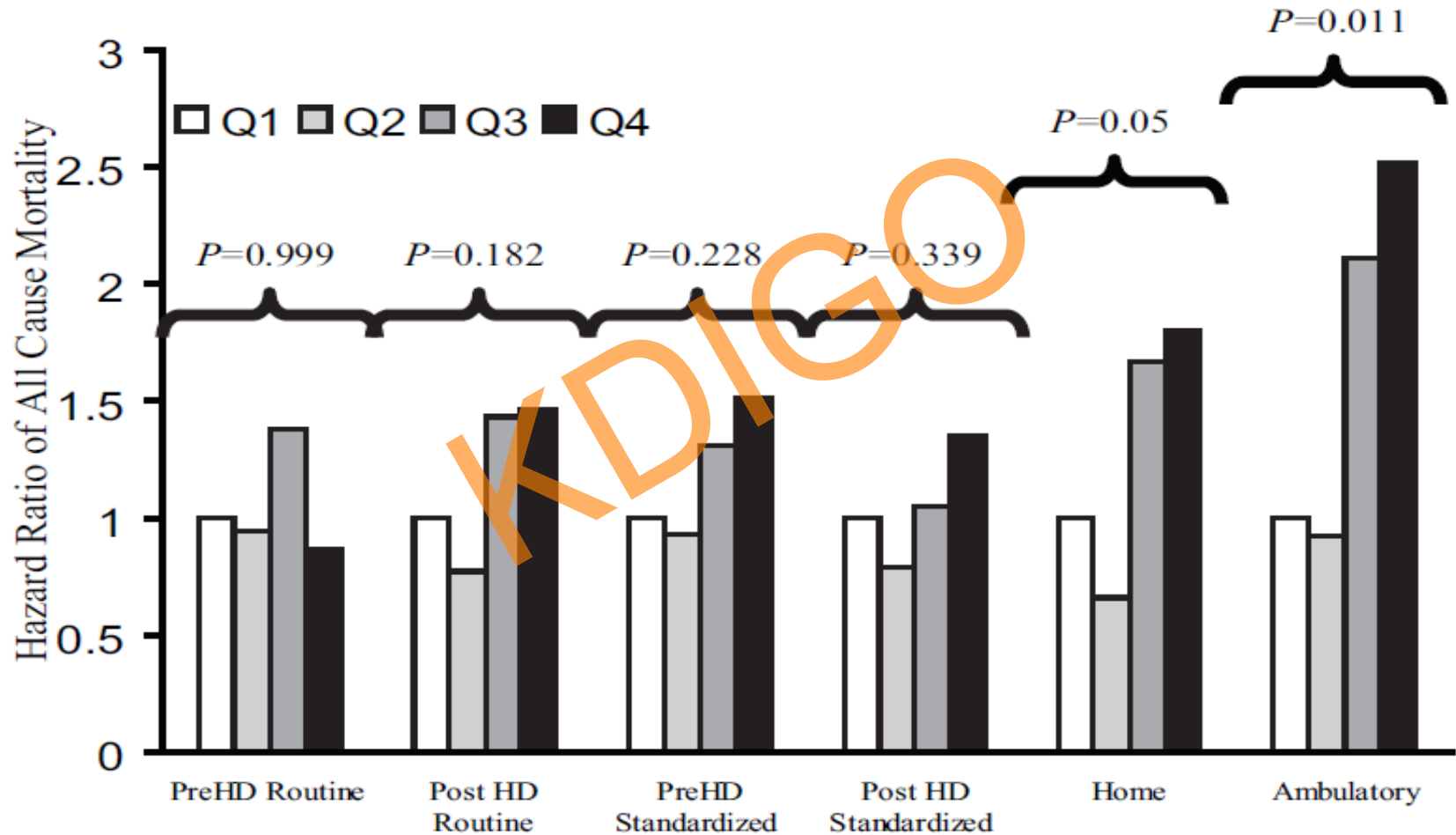
* 2-week BPM

3 readings, Omron 907

Pre- and post-dialysis

Agarwal R, et al. *Am J Nephrol* 2008;28:210-7.

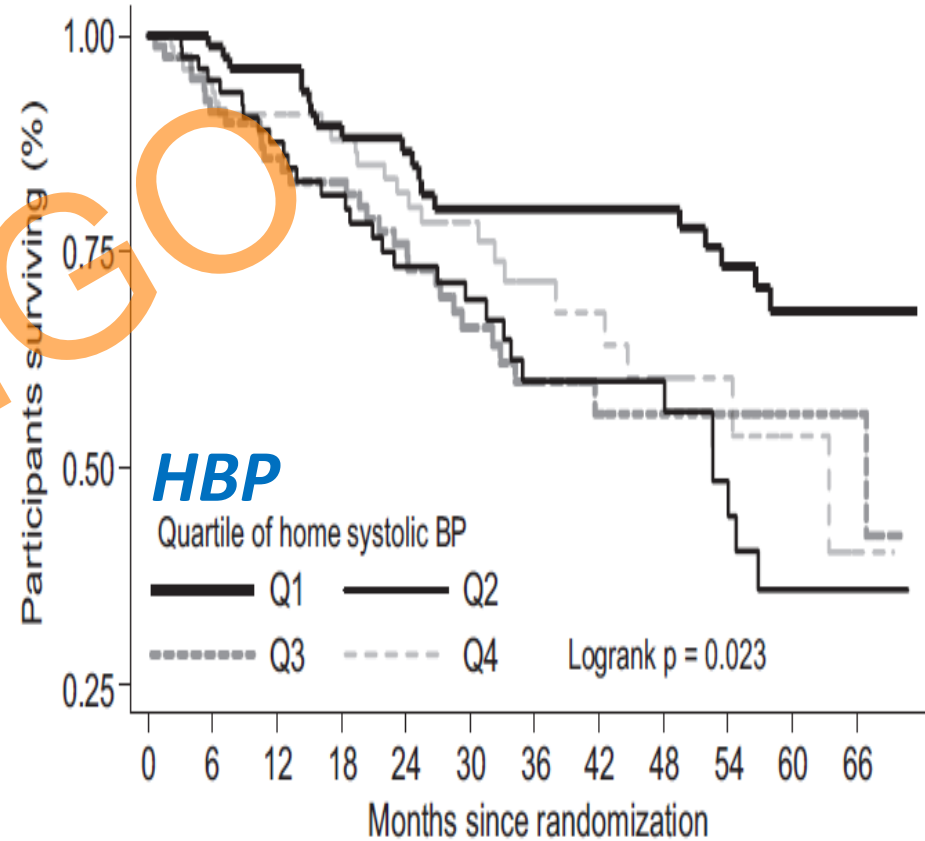
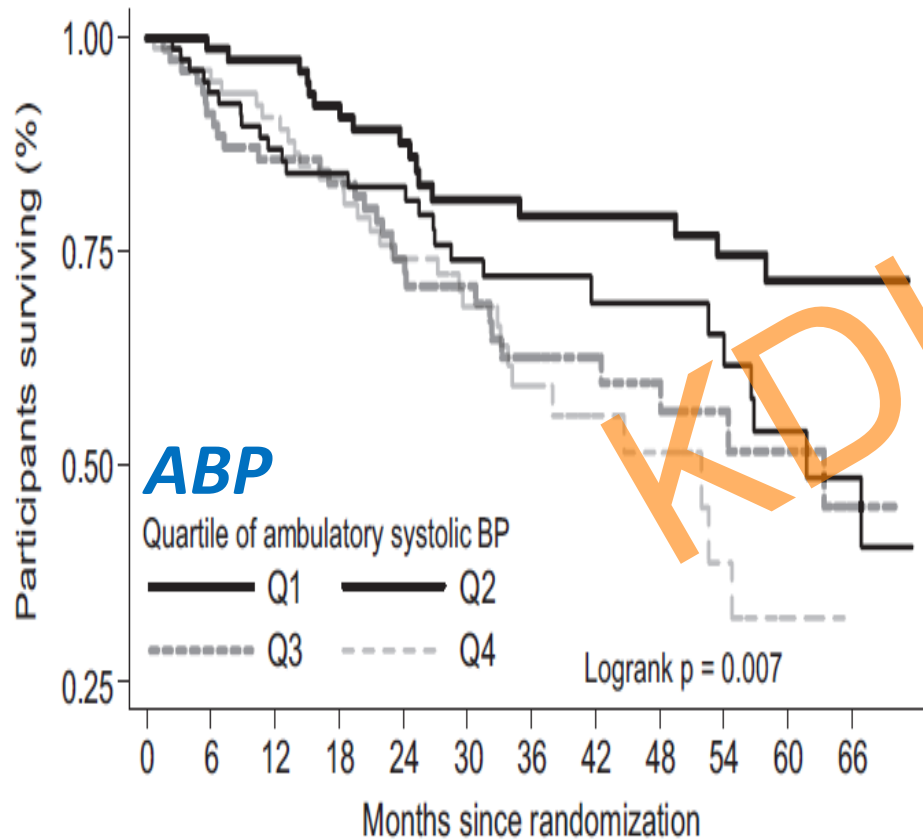
ABP/HBP has Greater Prognostic Value than Hemodialysis Unit BP



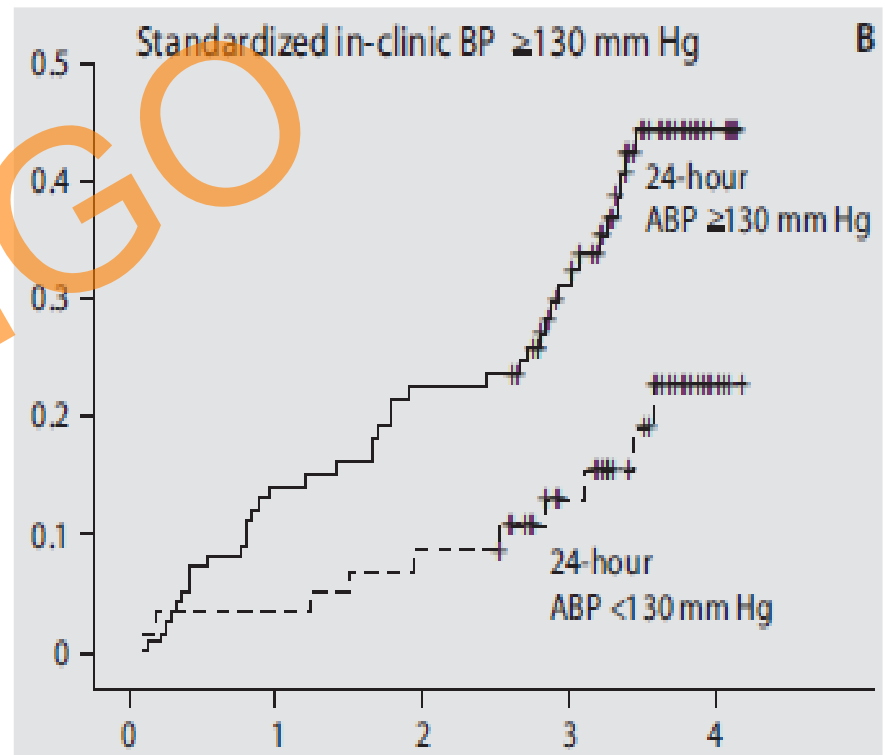
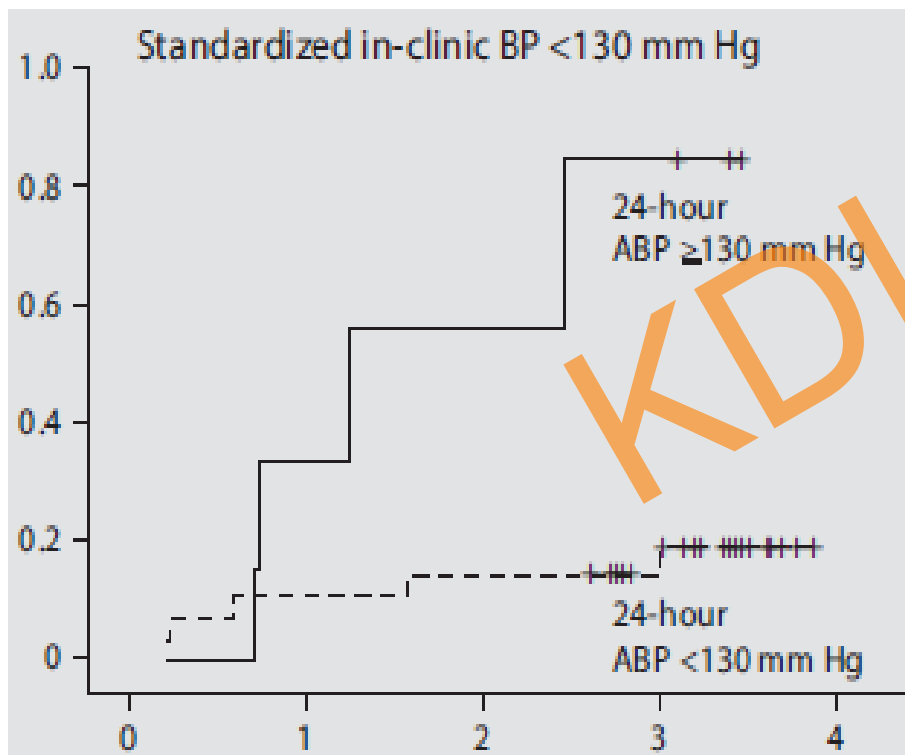
CKD
N=150

Alborzi P, Patel N, Agarwal R.
Clin J Am Soc Nephrol 2007;2:1228-34.

ABP/HBP and Mortality Among Hemodialysis Patients



OBP, ABP and CV Events in CKD



N=217, 3.4 ys

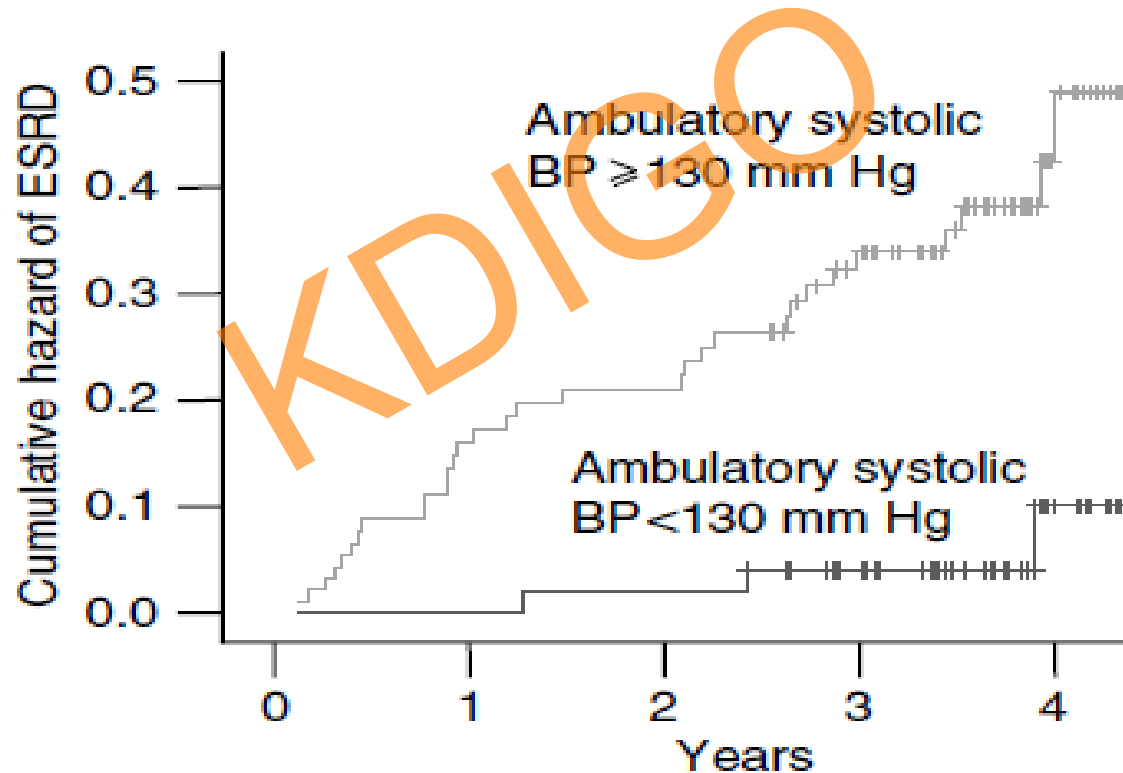
Agarwal R, et al. *Am J Nephrol* 2006;26:503-10.

**ABP/HBP
IN CKD**

RENAL ENDPOINTS

ABP and **ESRD** Risk in CKD

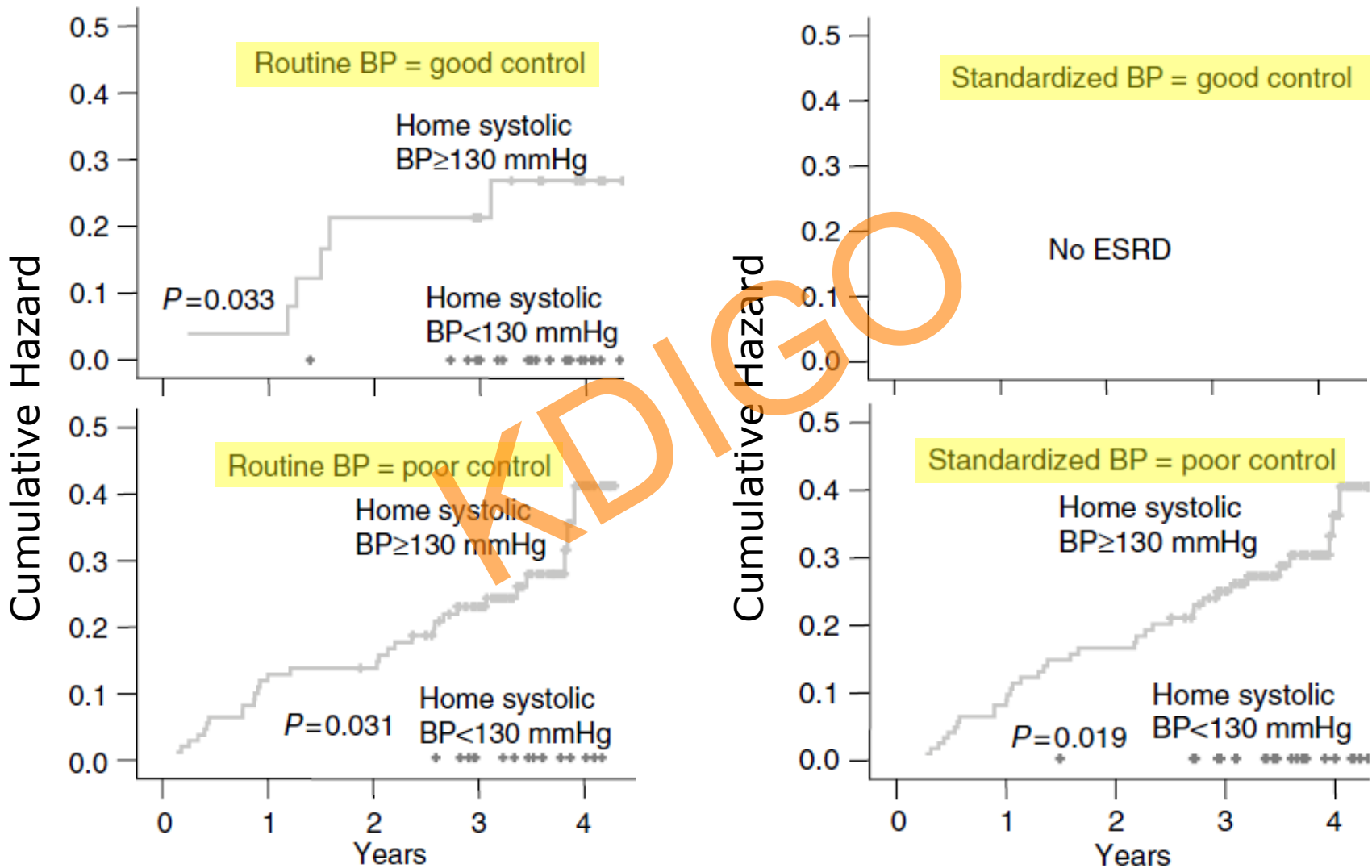
ESRD risk in high clinic SBP



N=217, 3.5 ys

Agarwal R, et al. *Kidney Int* 2006;69:1175-80.

HBP and Renal Events in CKD



N=217, 3.5 ys

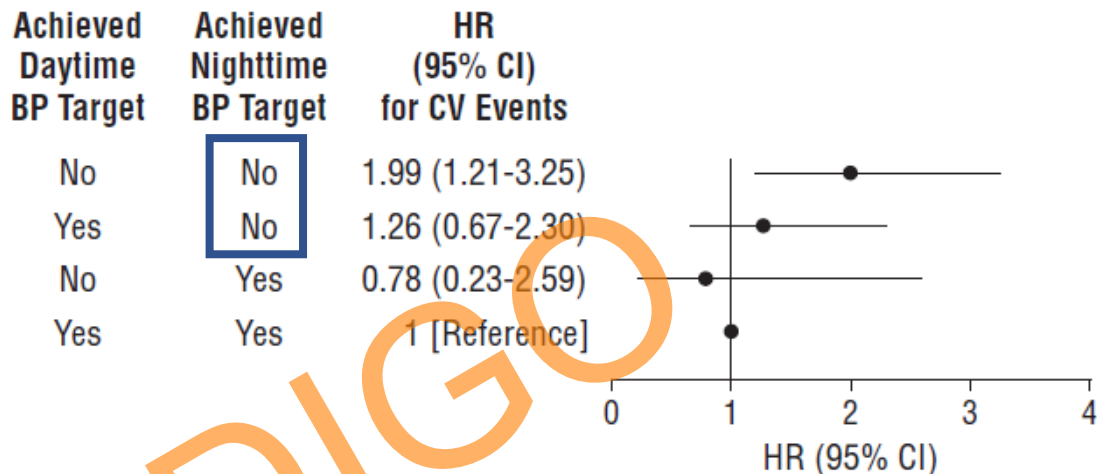
Agarwal R, et al. *Kidney Int* 2006;69:406-11.

NOCTURNAL BP AND DIP

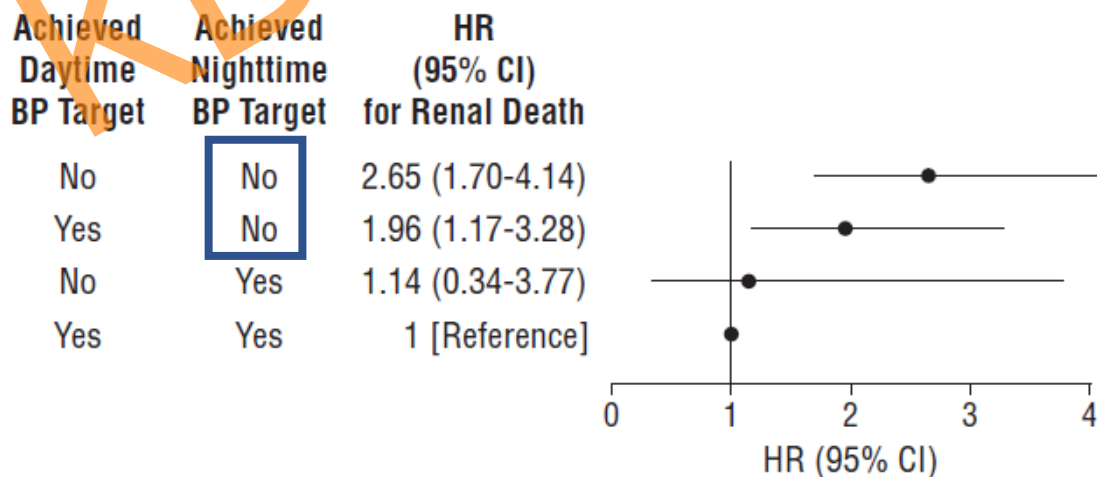
KDIGO

ABP in Nondialysis CKD

**CV
Event
Risk**



**Renal
Death
risk**

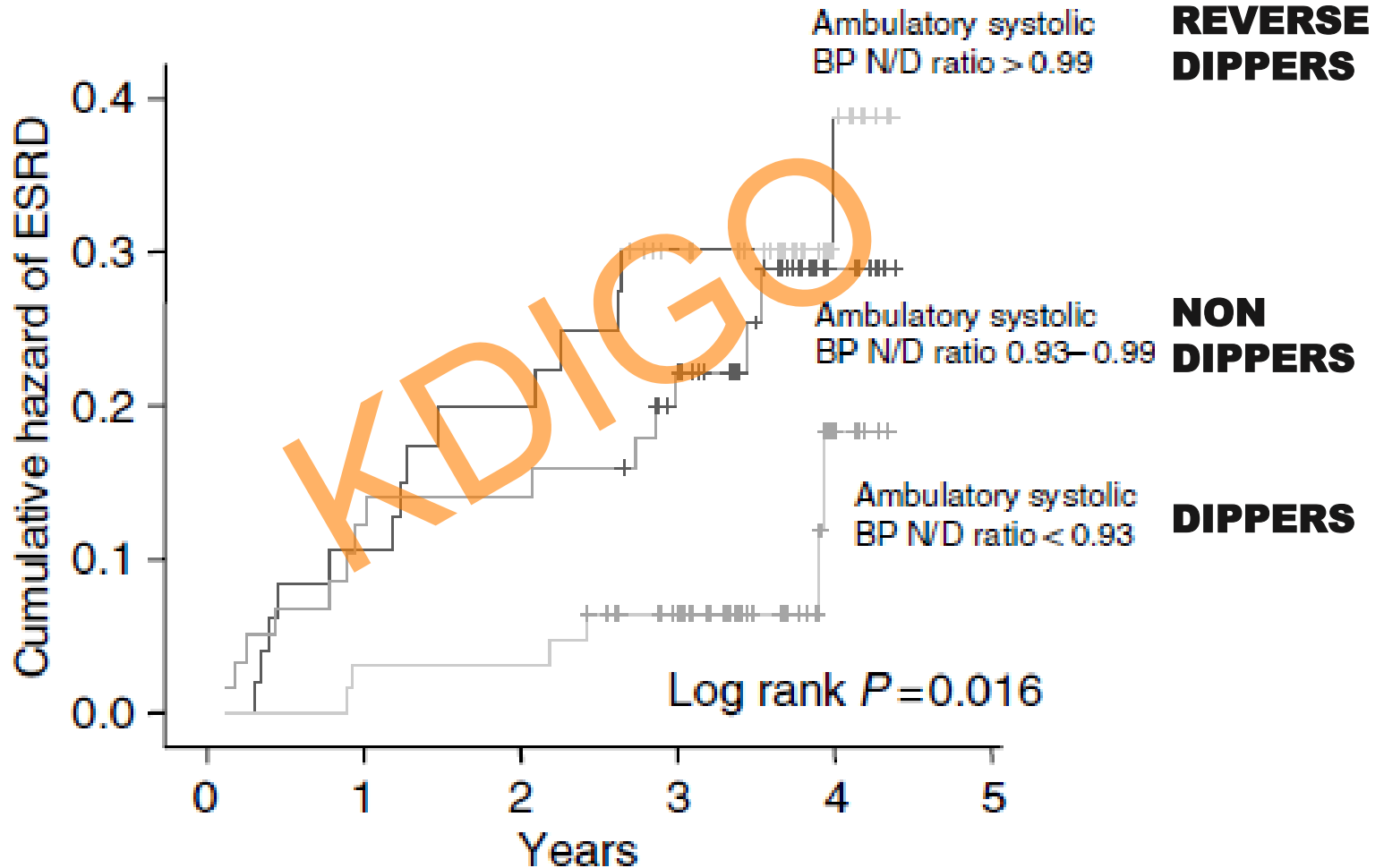


N=436

4,2 years

Minutolo R, et al. *Arch Intern Med* 2011;171:1090-8.

Nocturnal ABP Dipping and ESRD in CKD

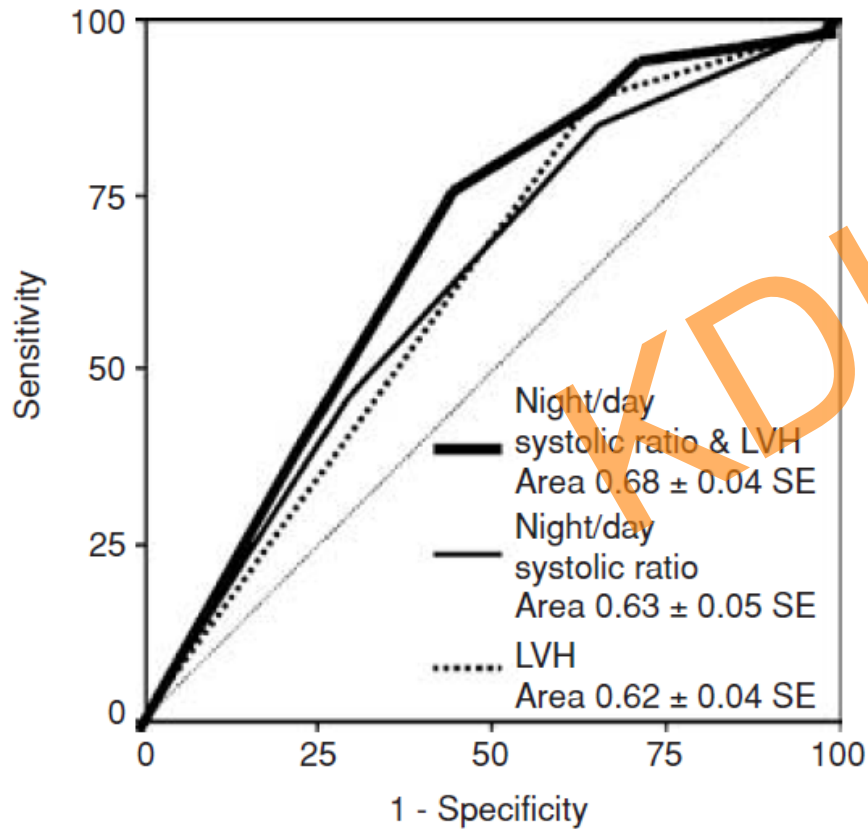


N=217, 3.5 ys

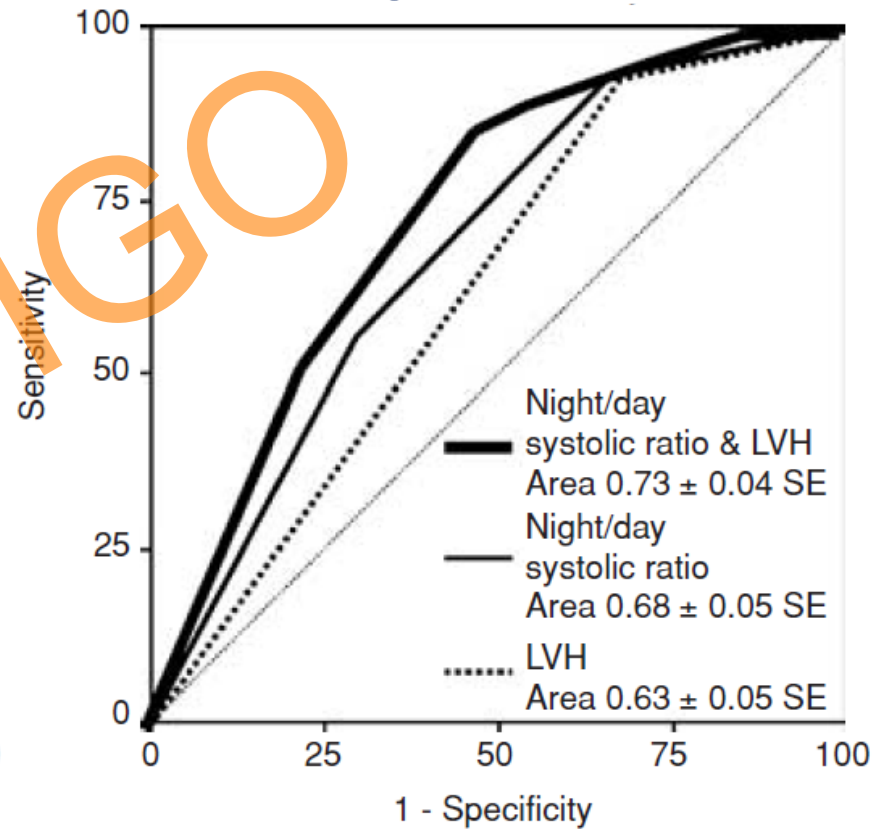
Agarwal R, et al. *Kidney Int* 2006;69:1175-80.

Prognostic Value of ABP and Night/Day Ratio in Hemodialysis Patients

TOTAL MORTALITY



CARDIOVASCULAR MORTALITY



N=168, 38 months

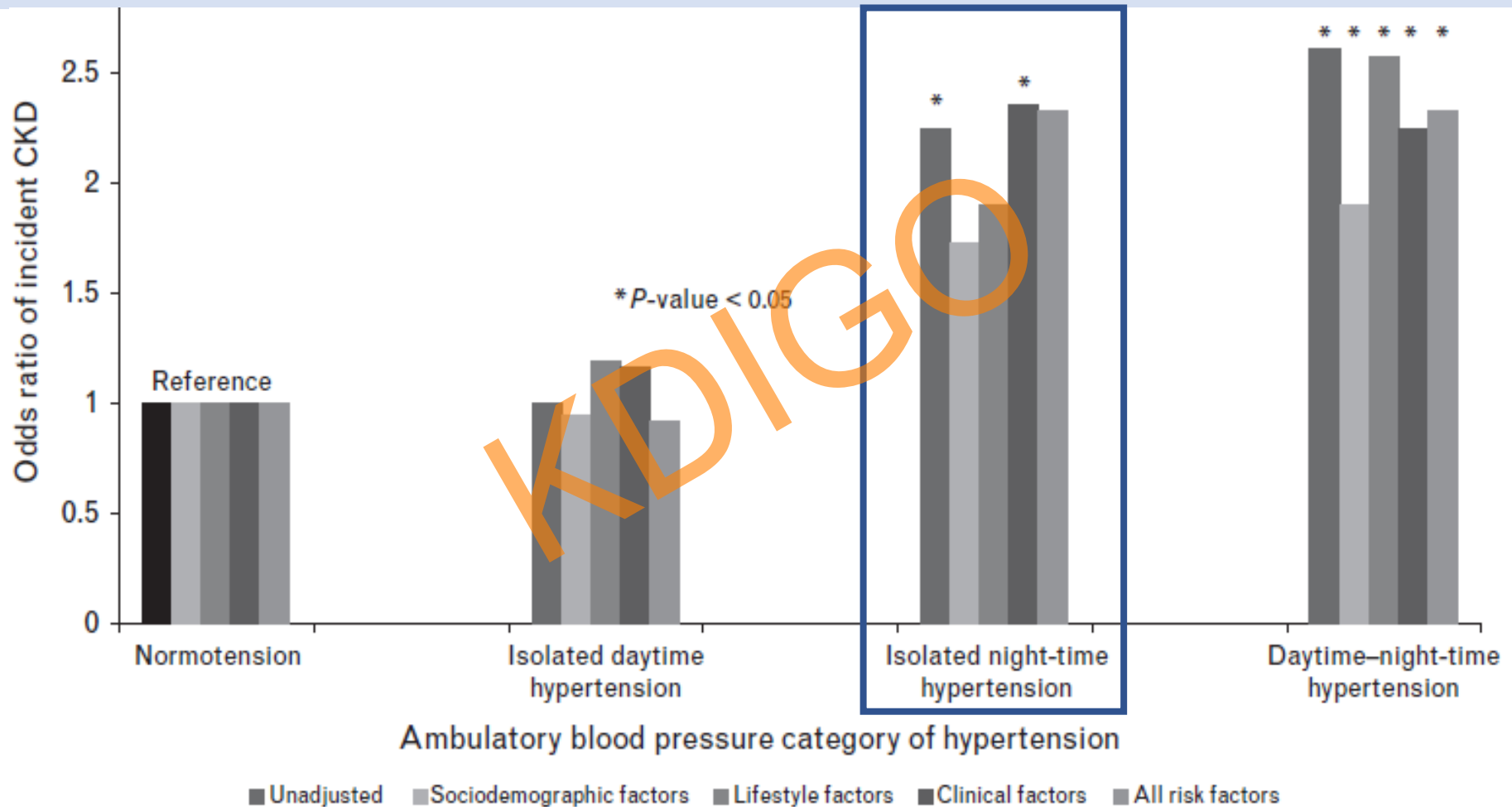
Nondiabetic, CVD free

Tripepi G, et al. *Kidney Int* 2005;68:1294-302.

GENERAL POPULATION OUTCOME STUDIES

**WITH
RENAL ENDPOINTS**

ABP and CKD in General Population: *Jackson Heart Study*



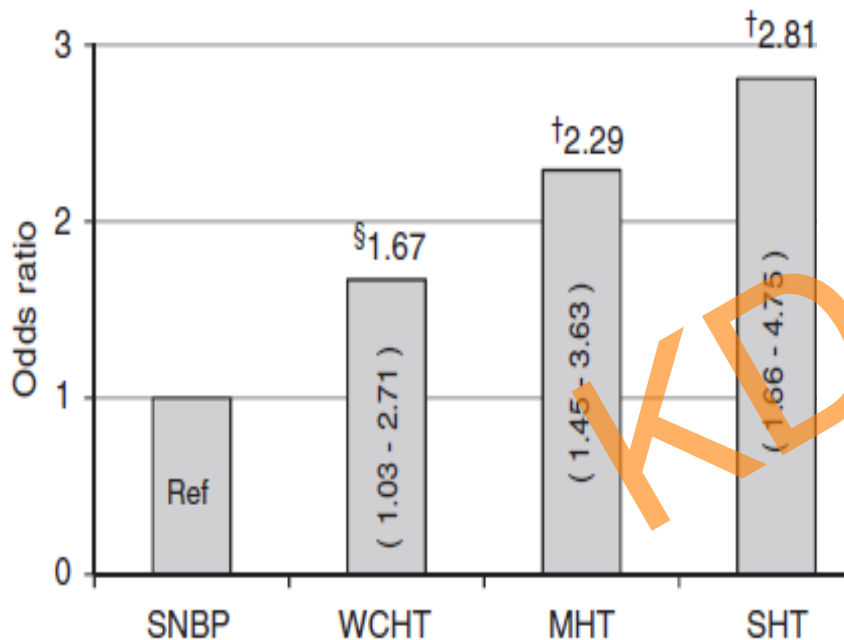
N=603, 8.1 years

African Americans

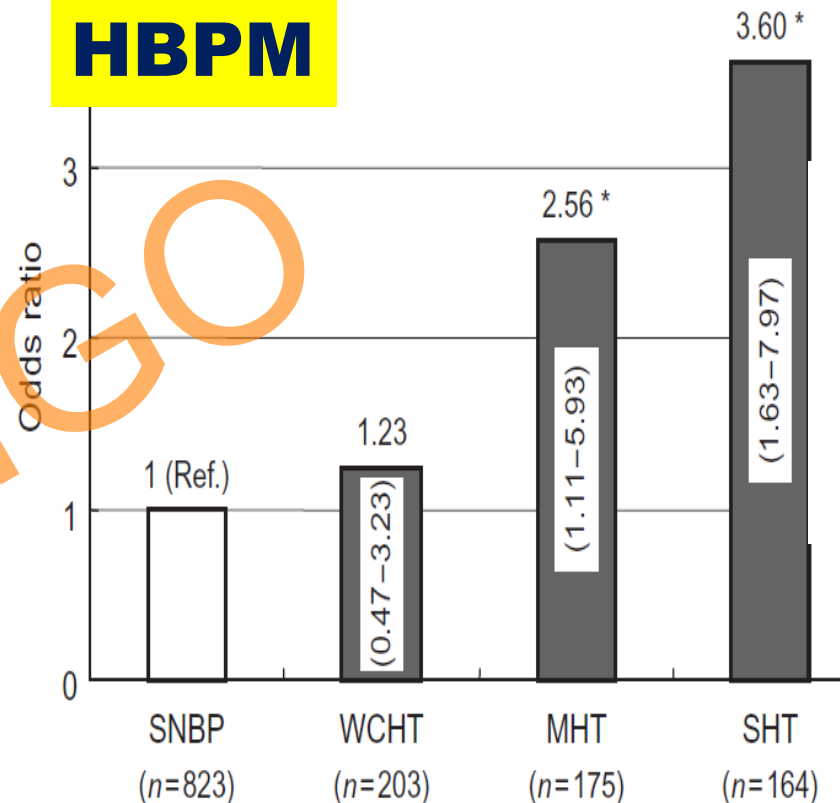
McMullan C, et al. *J Hypertens* 2015;33:1939-46.

White-coat and Masked HTN and CKD (Ohasama)

ABPM



HBPM



N=1,023, Cross-sectional
 Kanno A, et al. *Hypertens Res* 2010;33:1192-8.

**Proteinuria
 +
 eGFR <60**

N=1,365, Cross-sectional
 Terawaki H, et al. *Hypertens Res* 2008;31:2129-35.

Night-time BP and CKD in a General Population: Ohasama Study

HR for CKD

(/1SD ↑ SBP)

Day 1.13

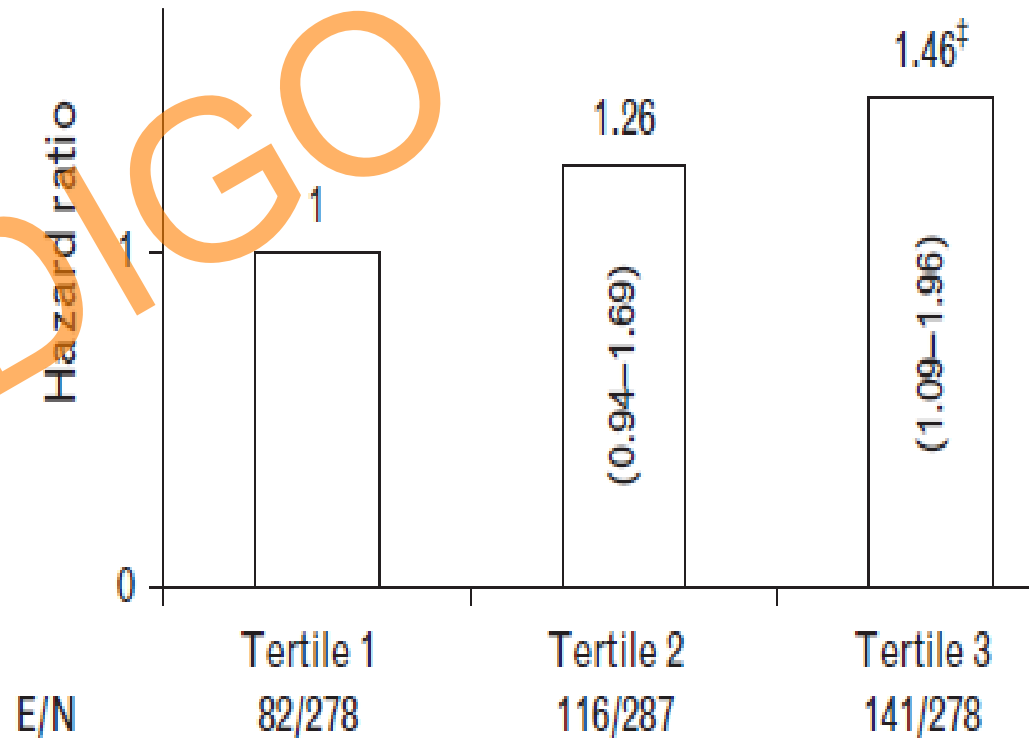
(0.97-1.30)

Night 1.21*

(1.04-1.39)

*Even adjusted for
daytime SBP*

CKD or All-cause Death



N=843, 8.3 years

**N=220 developed
proteinuria or eGFR <60**

Kanno A, et al. *J Hypertens* 2013;31:2410-7.

BPM and BPV in CKD

BPM

Articles

- | | | |
|---|---------------------------|----|
| ○ | White-coat and Masked HTN | 9 |
| ○ | Nocturnal BP and Dip | 14 |
| ○ | ABPM/HBPM and TOD | 15 |
| ○ | ABPM/HBPM and Outcome | 22 |
| ○ | Oscillometric BPM | 6 |

BPV

- | | | |
|---|-----------------------------|---|
| ○ | VVV, ABPV, HBPV and TOD | 9 |
| ○ | VVV, ABPV, HBPV and Outcome | 8 |

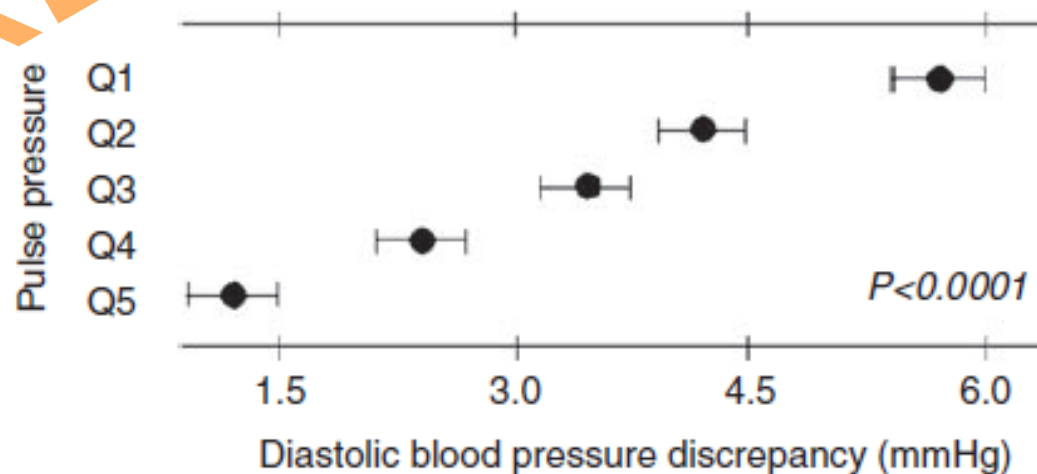
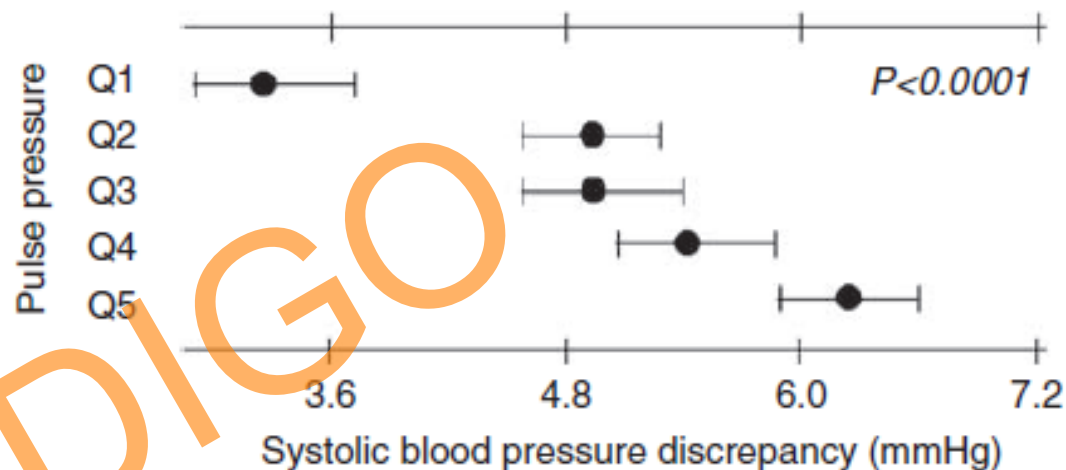
Unreliable oscillometric blood pressure measurement: prevalence, repeatability and characteristics of the phenomenon

5,070 BP readings

1,706 visits

755 patients

BpTRU vs.
mercury



Stergiou GS, et al.

J Hum Hypertens 2009;23:794-800.

Validation Studies of Oscillometric BPM Devices in CKD (4) - 3 devices

STUDY	DEVICE	PROTOCOL	RESULT
Thompson A, ..., Pickering TG. <i>Blood Press Monit</i> 2007;12:227-32	Microlife 3AC1-1PC	ESH-IP (N=33)	PASS
Czarkowski M, et al. <i>Blood Press Monit</i> 2009;14:232-8	Omron HEM-907	ESH-IP (N=33)	FAIL
Akpolat T, et al. <i>Kidney Blood Press Res</i> 2012;35:82-8	Omron HEM-7051-E	ESH-IP2 (N=66)	PASS
Cohen JB, Alpert B, ..., et al. <i>J Clin Hypertens</i> 2017; 19:296-302	Omron HEM907XL	AAMI (N=85)	FAIL

Automated Office BP Measurement (AOBP) in CKD (BpTRU) (2)

STUDY	N	RESULT
Brothwell S, et al. <i>BMC Nephrol</i> 2013; 14:218.	91	<ul style="list-style-type: none">• Lower than <u>routine clinic BP</u>• Similar to <u>day</u> and <u>24 h ABP</u>
O'Shaughnessy MM, et al. <i>Blood Press Monit</i> 2011;16:124-8.	80	<ul style="list-style-type: none">• Lower than <u>routine clinic BP</u>

BPM and BPV in CKD

BPM

Articles

- White-coat and Masked HTN 9
- Nocturnal BP and Dip 14
- ABPM/HBPM and TOD 15
- ABPM/HBPM and Outcome 22
- Oscillometric BPM 6

BPV

- VVV, ABPV, HBPV and TOD 9
- VVV, ABPV, HBPV and Outcome 8

BP Variability Types

OBP

11

Visit-to-visit

Long-term

HBP

3

Day-to-day

Medium-term

ABP

3

Reading-to-reading

Short-term

OBP VVV in CKD (11)

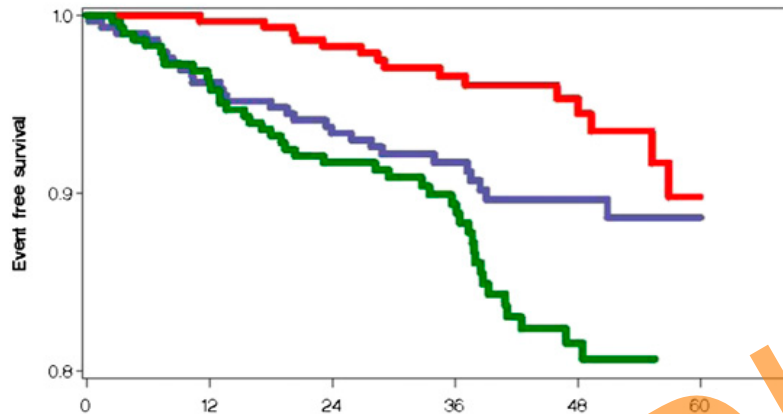
Study	Country	Design	Subjects	N	OBP	Duration /Visits	BPs /Visit	VVV type	VVV Index	AIM
<i>Chang et al. 2017</i>	USA	Retropective	CKD	114,900	Auscult or oscil	6 m / ?	?	SBPV	SD, CV, ARV	Prognosis
<i>McMullan et al. 2013</i>	USA AASK	Prospective	CKD Afr.Am	908	Auscult RZ	12 m / 6	2	SBPV	SD	Prognosis
<i>Mallamaci et al. 2013</i>	Italy	Prospective	CKD	1,618	Auscult	37 m / 2-7	3	SBPV, DBPV	SD, CV, max	Prognosis
<i>Di Iorio et al. 2012</i>	Italy	Prospective	CKD	374	Oscil	4 m / 4	?	SBPV, DBPV	CV	Prognosis
<i>Jo et al. 2015</i>	S Korea	Prospective	Perit. dialysis	216	Oscil	24 m / ?	?	SBPV	SD	Prognosis
<i>Chang et al. 2014</i>	USA	Prospective	Hemo-dialysis	1,844	Auscult	2-56 ds / ?	?	Pre-, post-dial. SBPV	SD, ARV	Prognosis
<i>Nakano et al. 2014</i>	Japan	Prospective	CKD	150	Oscil	48 m / 10	1	SBPV	SD, CV, max-min	TOD
<i>Yokota et al. 2014</i>	Japan	Retro-spective	CKD DM	127	Auscult	32 m / 12	2	SBPV, DBPV	SD, CV, max-min, max	TOD
<i>Yokota et al. 2012</i>	Japan	Retro-spective	CKD Non-DM	56	Auscult	83 m / 12	2	SBPV, DBPV	SD, CV, max-min, max	TOD
<i>Azushima et al. 2017</i>	Japan	Cross sectional	CKD	76	Auscult	Within-visit BPV	3	SBPV	CV	Risk factors for high BPV
<i>Hong et al. 2016</i>	USA AASK	Prospective	CKD Afr.Am	988	Auscult RZ	12 m / 6	2	SBPV	SD, CV, ARV	VVV and adherence

OBP - VVV in CKD (11)

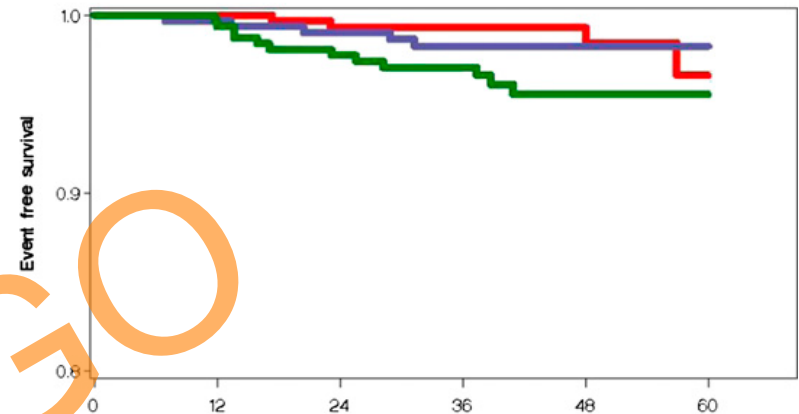
Study	Country	Design	Subjects	N	KEY RESULTS
<i>Chang et al. 2017</i>	USA	Retrospective	CKD	114,900	↑ Total mortality, hemorrhagic stroke
<i>McMullan et al. 2013</i>	USA AASK	Prospective	CKD Afr. Am	908	↑ CV, total mortality
<i>Mallamaci et al. 2013</i>	Italy	Prospective	CKD	1,618	↑ CV, total mortality
<i>Di Iorio et al. 2012</i>	Italy	Prospective	CKD	374	↑ Total mortality NOT Progression to dialysis
<i>Jo et al. 2015</i>	S Korea	Prospective	Perit dialysis	216	NOT CV events, death ↓ Residual renal function
<i>Chang et al. 2014</i>	USA	Prospective	Hemo-dialysis	1,844	↑ CV, total mortality
<i>Nakano et al. 2014</i>	Japan	Prospective	CKD	150	↓ eGFR and ↓ Flow-mediated dilation
<i>Yokota et al. 2014</i>	Japan	Retrospective	CKD DM	127	NOT ↓ eGFR
<i>Yokota et al. 2012</i>	Japan	Retrospective	CKD Non-DM	56	↓ eGFR
<i>Azushima et al. 2017</i>	Japan	Cross sectional	CKD	76	CV risk factors NOT Renal vascular/functional parameters
<i>Hong et al. 2016</i>	USA AASK	Prospective	CKD Afr.Am	988	↓ Med adherence

OBP - VVV in CKD

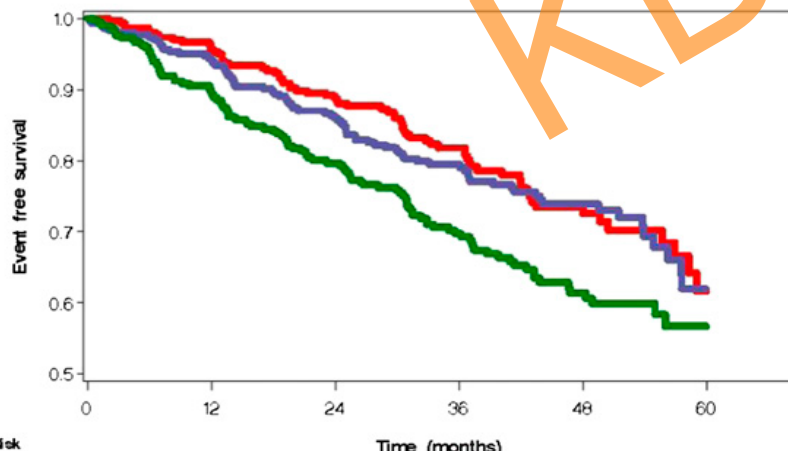
OVERALL SURVIVAL



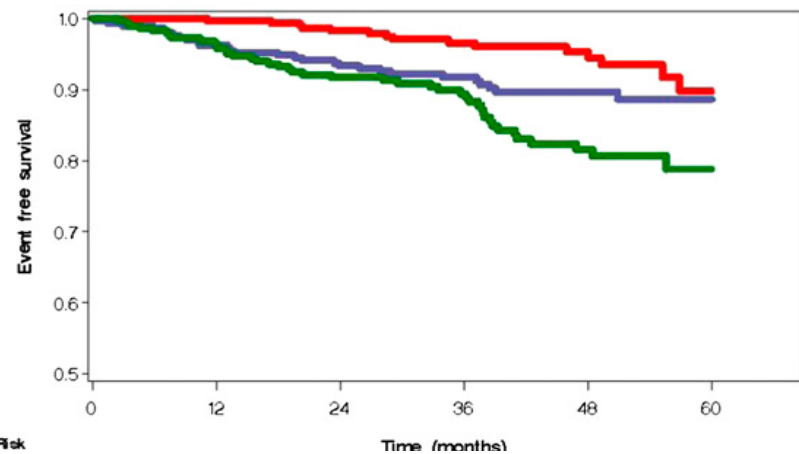
CVD SURVIVAL



RENAL EVENT FREE SURVIVAL



CVD EVENT FREE SURVIVAL



Number at Risk

Time (months)

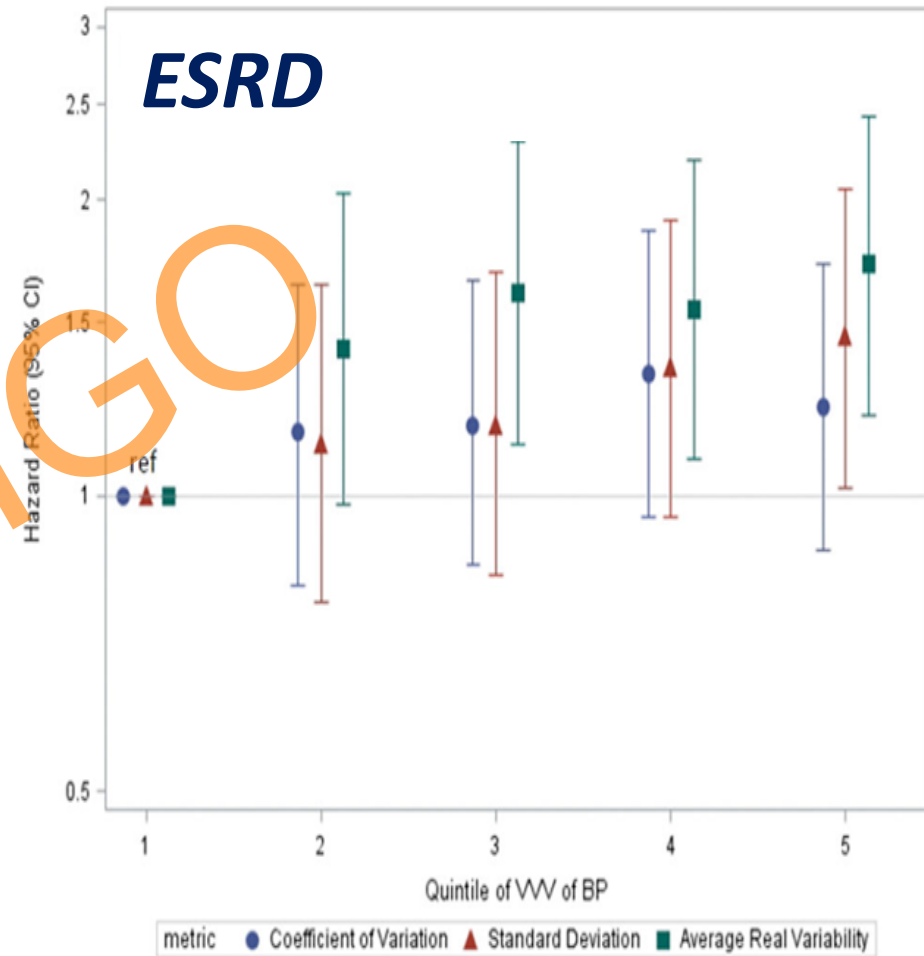
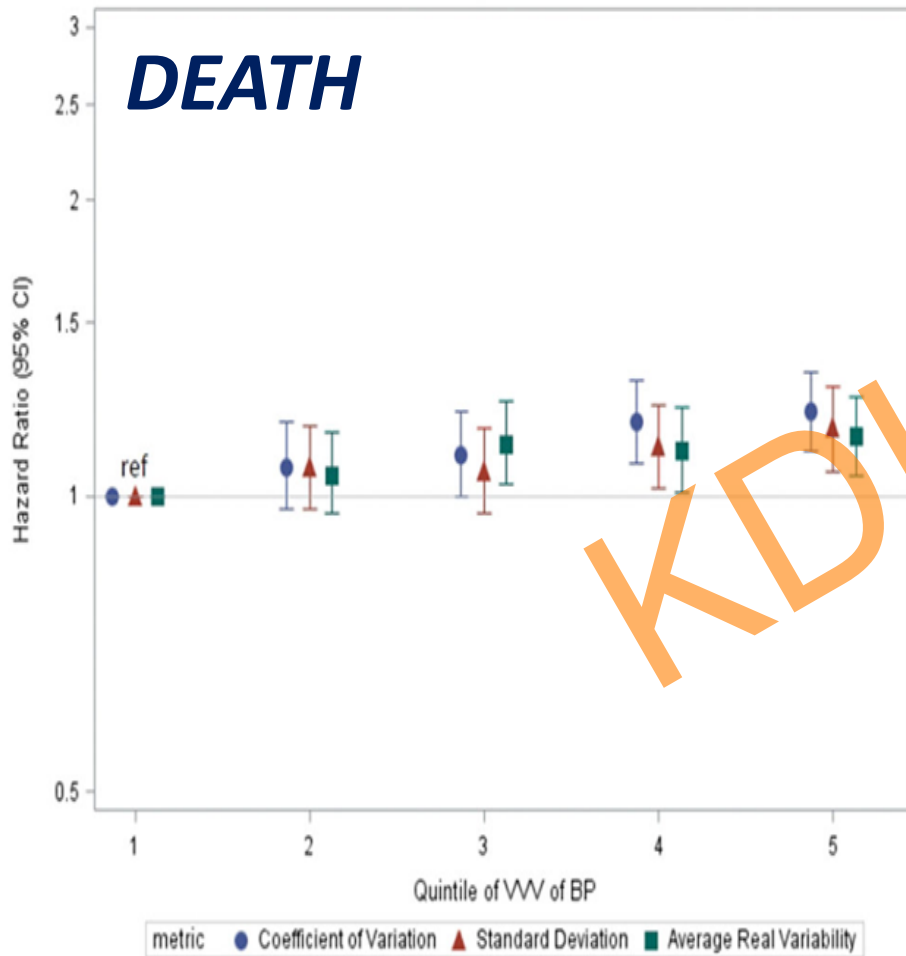
Number at Risk

Time (months)

AASK, N=908
US Afr/Am (SD)

McMullan CJ, et al. *Clin J Am Soc Nephrol* 2013;8:731-8.

OBP - VVV in CKD

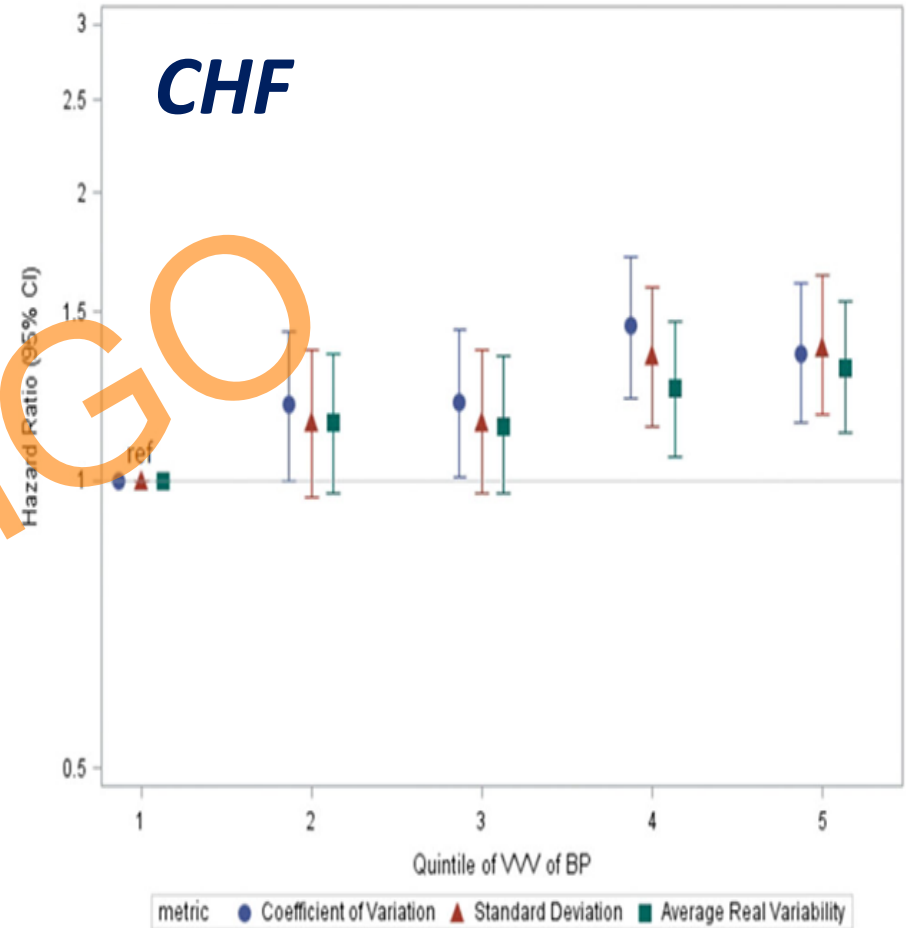
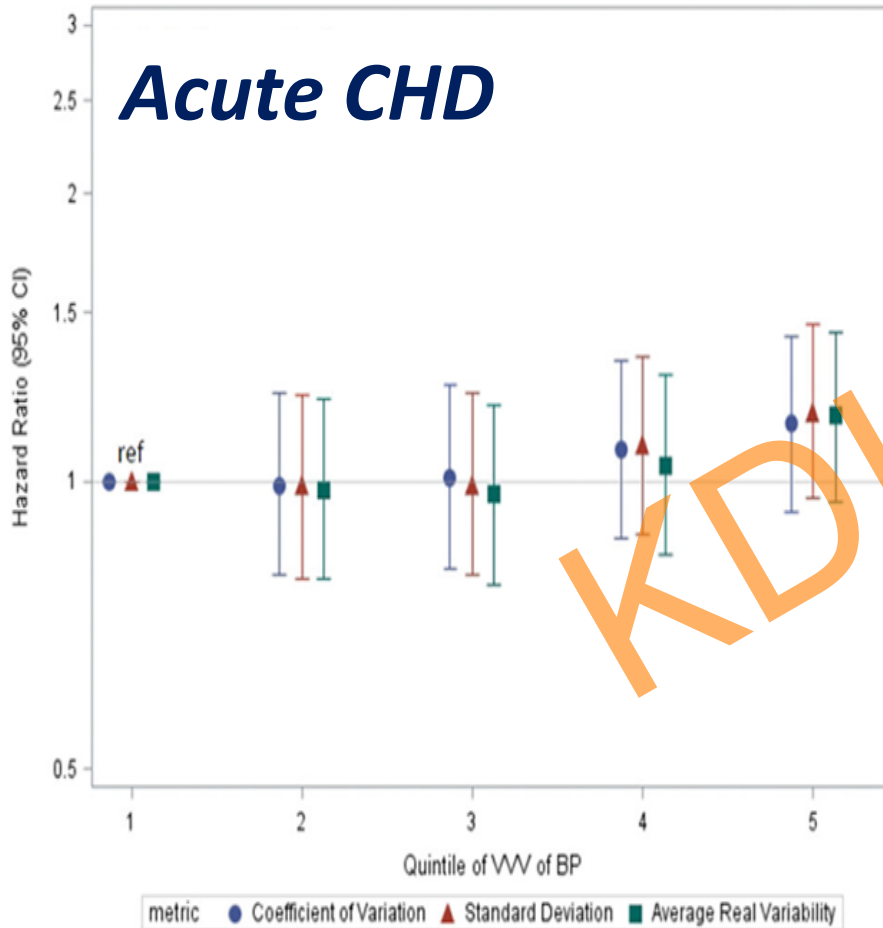


KDIGO

N=114,900, CKD 3-4
USA Kaiser Permanente

Chang TI, et al. *J Hypertens* 2016;34:244-52.

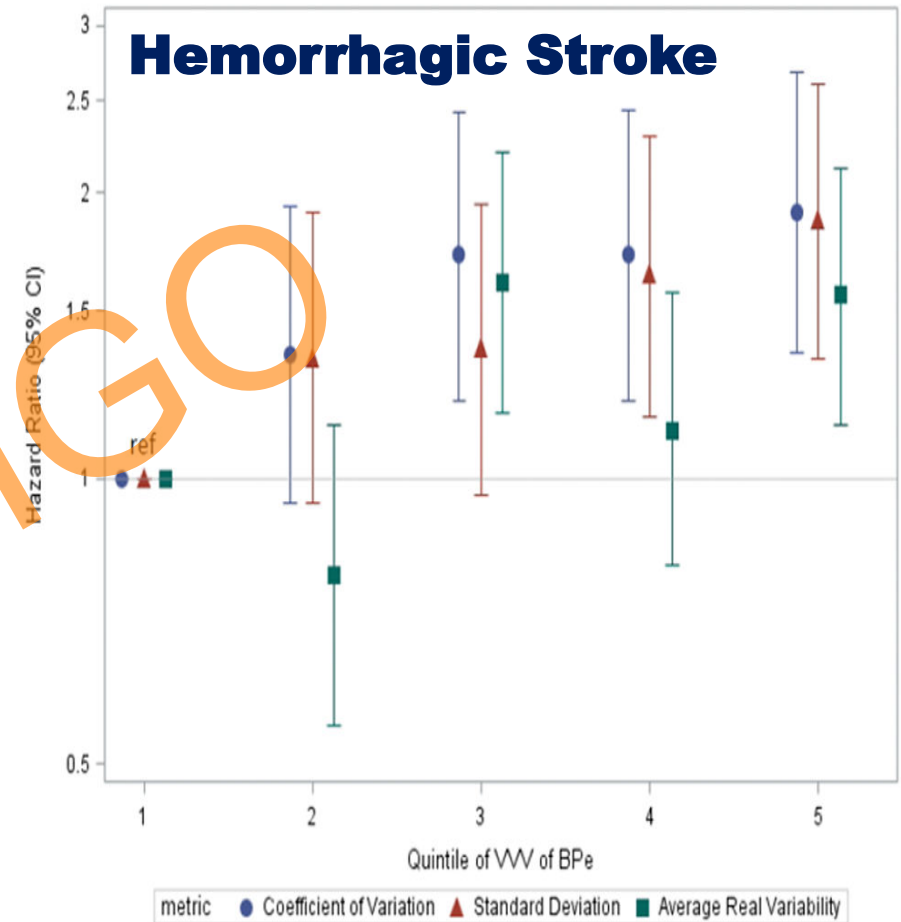
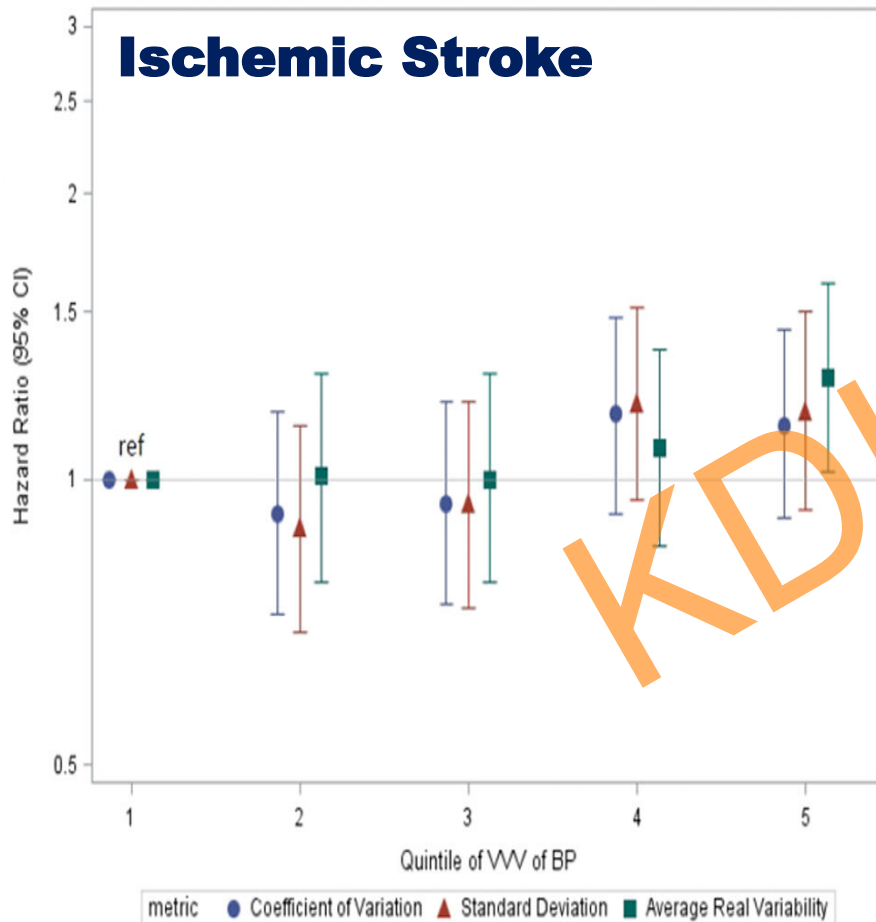
OBP - VVV in CKD



N=114,900, CKD 3-4
USA Kaiser Permanente

Chang TI, et al. *J Hypertens* 2016;34:244-52.

OBP - VVV in CKD

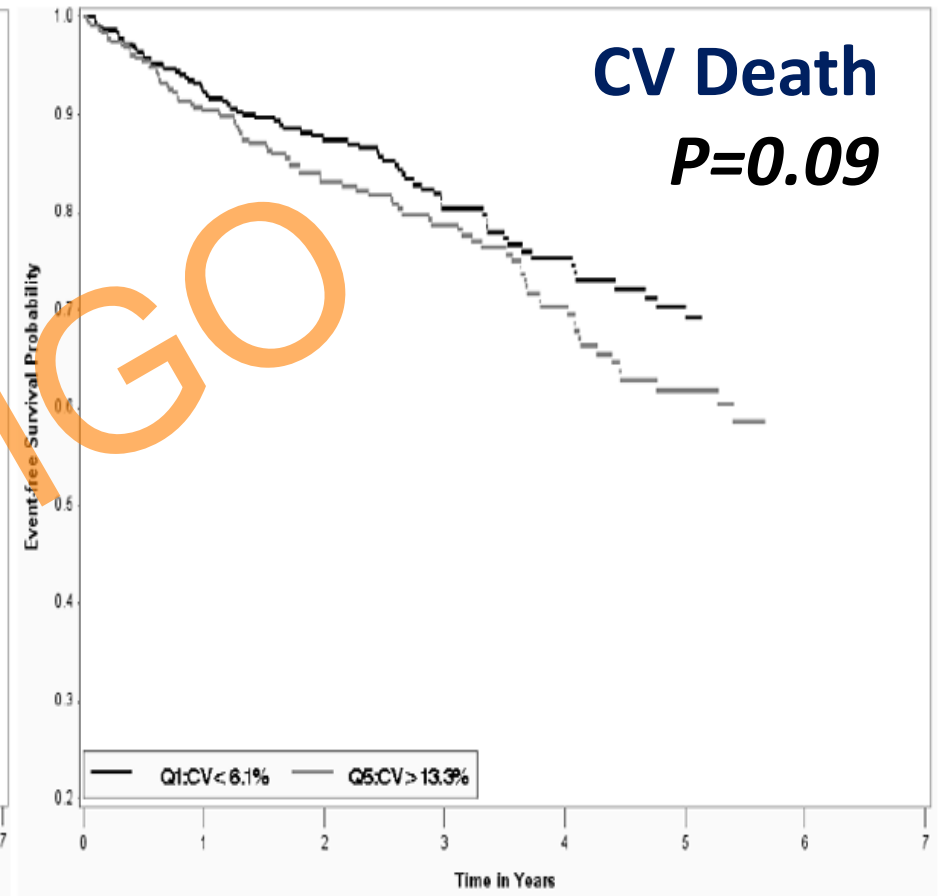
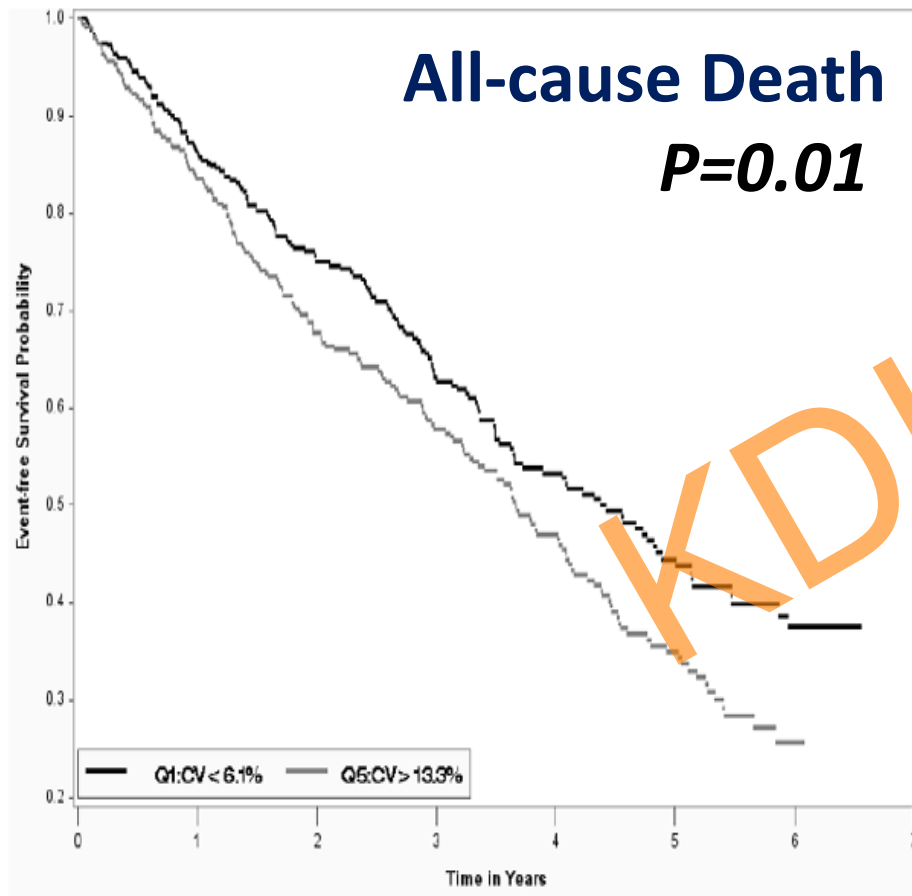


KIDINGO

N=114,900, CKD 3-4
USA Kaiser Permanente

Chang TI, et al. *J Hypertens* 2016;34:244-52.

OBP - VVV in CKD



Pre-dialysis SBP VVV quintile Q1 vs. Q5

Chang TI, et al. *J Hum Hypertens* 2014;28:18-24.

**N=1,846, USA
Hemodialysis**

Home BP Variability (3)

Study	Country	Design	Subjects	N	HBP time/n/days	KEY FINDING
<i>Okada et al. 2012</i>	<i>Japan</i>	Prospective	CKD	135	m&e/1/7 every 6 m for 36 m	NOT associated with ↓ eGFR
<i>Okada et al. 2008</i>	<i>Japan</i>	Prospective	CKD	368	m&e/1/7 every 6 m for 24 m	NOT associated with ↓ eGFR
<i>Ushigome et al. 2011</i>	<i>Japan</i>	Cross-sectional	DM-2	858	m&e/3/14	Associated with proteinuria

ABP RRV in CKD (3)

Study	Country	Design	Subjects	N	ABPV type	ABPV Index	Key Finding
Ryu et al. 2014	S Korea	Cross-sectional	CKD	1,173	24h S/D	ARV	Association with LVH NOT with renal damage
Gorostidi et al. 2015	Spain ABPM Registry	Cross-sectional	HTN	14,382	Day Night S/D	SD	Association with CKD
Tanner et al. 2015	USA Jackson Heart Study	Cross-sectional	Afr.Am.	1,022	24h S/D	SD weighted ARV	Association with CKD Largely explained by AVG BP

CONCLUSIONS

BPM

- **ABP/HBP essential for white-coat and masked HTN detection.**
- **ABP essential for nocturnal BP evaluation.**
- **ABP(HBP) superior to OBP in predicting TOD and CV(Renal) outcome.**
- **Oscillometric BPM accuracy (?)**

BPV

- **Strong prognostic data for OBP VVV.**

CONCLUSIONS

In CKD

OUT-OF-OFFICE BPM

even more crucial than for non-CKD

particularly ABPM

yet not for BP variability



BP MEASUREMENT AND VARIABILITY IN CKD

**George S. Stergiou
Konstantinos Kyriakoulis**

**Hypertension Center STRIDE-7
Third University Department of Medicine
Sotiria Hospital, Athens Greece**