

How to limit bias in observation studies analysis, Propensity score matching versus Logistic regression

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Agenda

- Introduction
- Methodology
- Examples on a Terumo's Study
- Conclusion

Introduction

Introduction

- In **RCT**, the randomization assign the group : exposure vs non-exposure.
This ensure similar distribution of covariates in both groups
→ Effect of treatment can be easily compared between groups
- In **observational studies** (retrospective studies or non-randomized studies), subjects are not randomly assigned and covariates are not similarly distributed in both groups
→ Confounding effect need to be removed when estimating effect of treatment.
- **How to ?**
 - Logistic Regression
 - Propensity Score Matching

Introduction

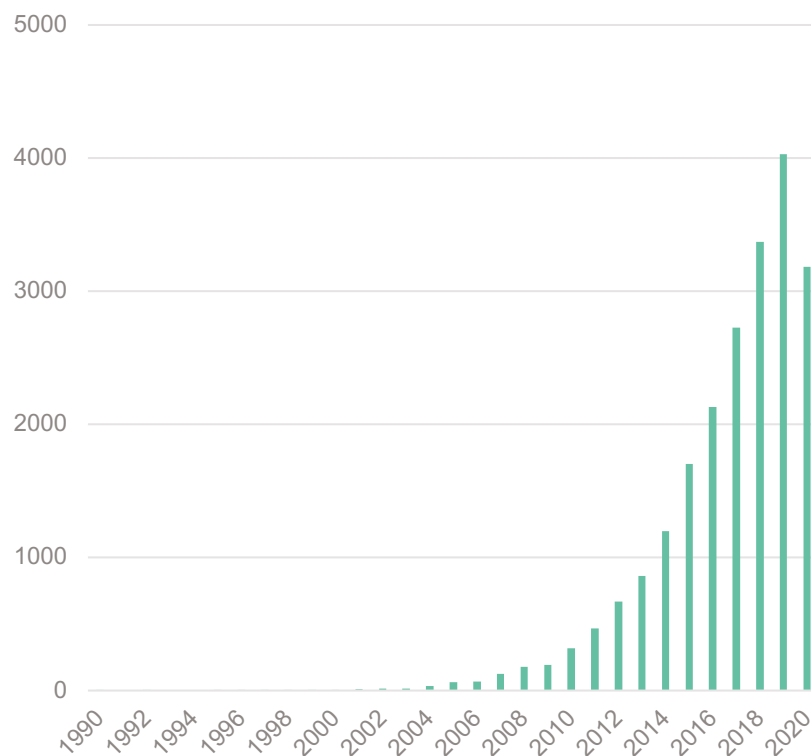
■ How to ?

- Logistic Regression (LR)
 - **Principle:** Estimates the treatment effect after adjusting for differences in the baseline covariates
 - Many practical limitations
- Propensity Score Matching (PSM)
 - **Principle:** PSM is defined as probability of assignment to treatment conditional on a set of observed baseline covariates. The basis for propensity score methods is the causal effect model.
 - Advantage: PSM minimizes the effects of confounding and offers some of the advantages of a randomized study.

Introduction

■ Propensity Score Matching (PSM), → Prehistoric or Modern Analysis technique ?

- Analysis technique introduced in 1983 by Paul R. Rosenbaum and Donald Rubin (US)
- N articles published on Pubmed increased from 2005 and continues to grow every year (2019, N = 4017).



■ Why ?

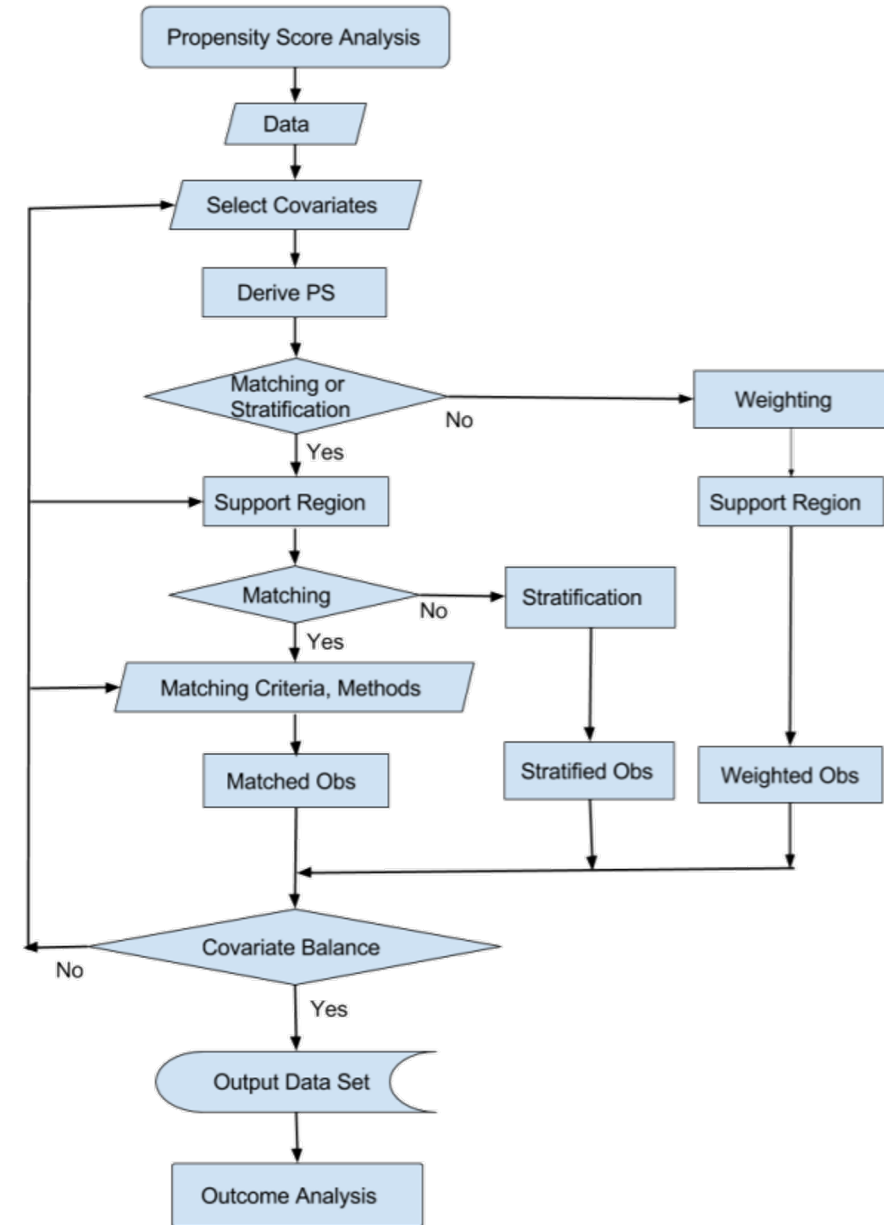
- Major increase in data collection (Registry, RWE data)
- More post-marketing surveillance study required by authorities
- Available in many programming environments :
 - **SAS**: by using PSMATCH procedure, and macro OneToManyMTCH
 - **R**: by using the MatchIt package
 - **STATA**: by using the user-written psmatch2 or teffects psmatch built in command (available after version 13)
 - **SPSS**: Dialog box for PSM available from the IBM SPSS Statistics Menu

Methodology

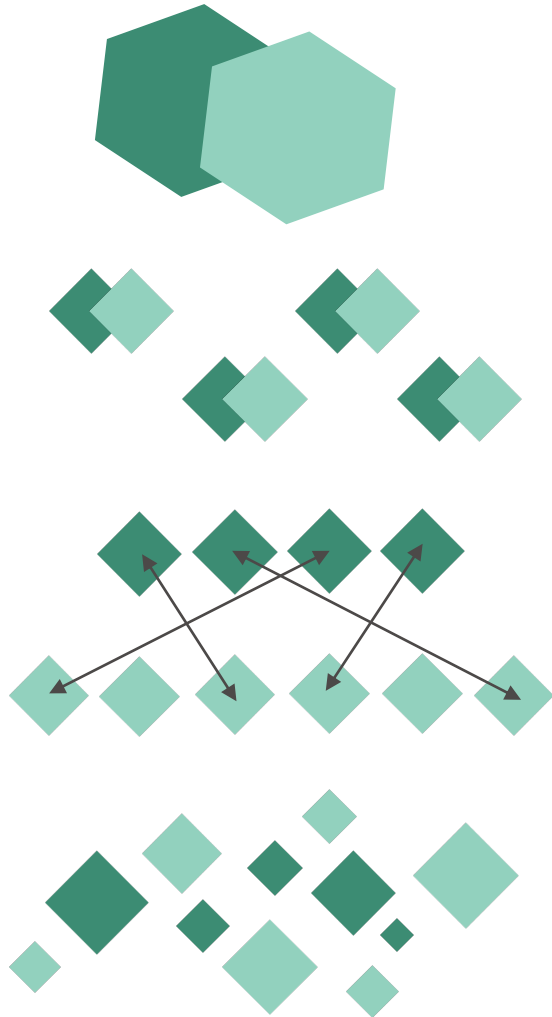
Methodology

■ General Procedure of Propensity-Score Matching

- Compute the propensity scores
 - Step 0: Check for imbalances between control and treatment group.
 - Step 1: Estimate the propensity model.
 - Step 2: Predict individual propensity score.
- Integrate the propensity score in the analysis
 - Step 3: Match controls on treated subjects.
 - Adjustment
 - Stratification
 - Matching
 - Step 4: Check if propensity score matching reduced the imbalances. If necessary, repeat 1 through 3.
 - Step 5: Estimate treatment effect.



Methodology

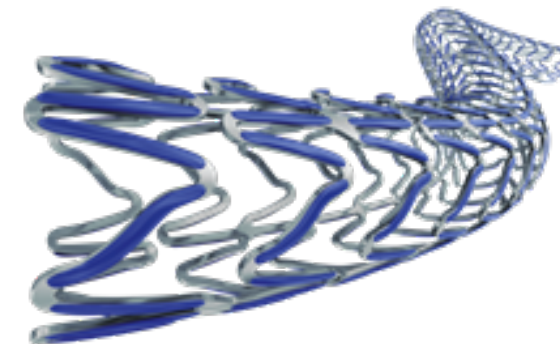


- Adjustment by using PS as regression covariate
- Stratification
- Matching
 - 3 techniques : Greedy nearest neighbor matching, Optimal matching and Matching with replacement.
 - Additional option : Caliper width setting
- Adjustment by Inverse probability of treatment weighting

Examples on a Terumo's Study

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More information available at : <https://www.terumo-europe.com/en-emea/clinicaldata/e-ultimaster-trial>



■ Study Description

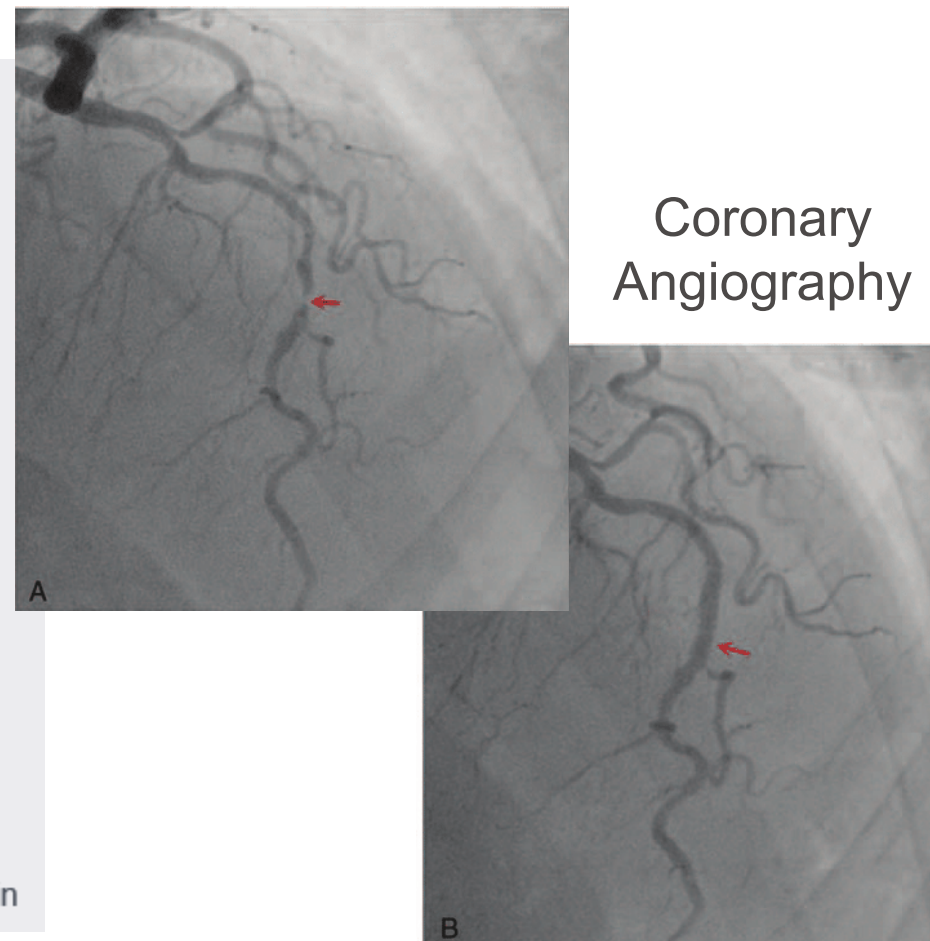
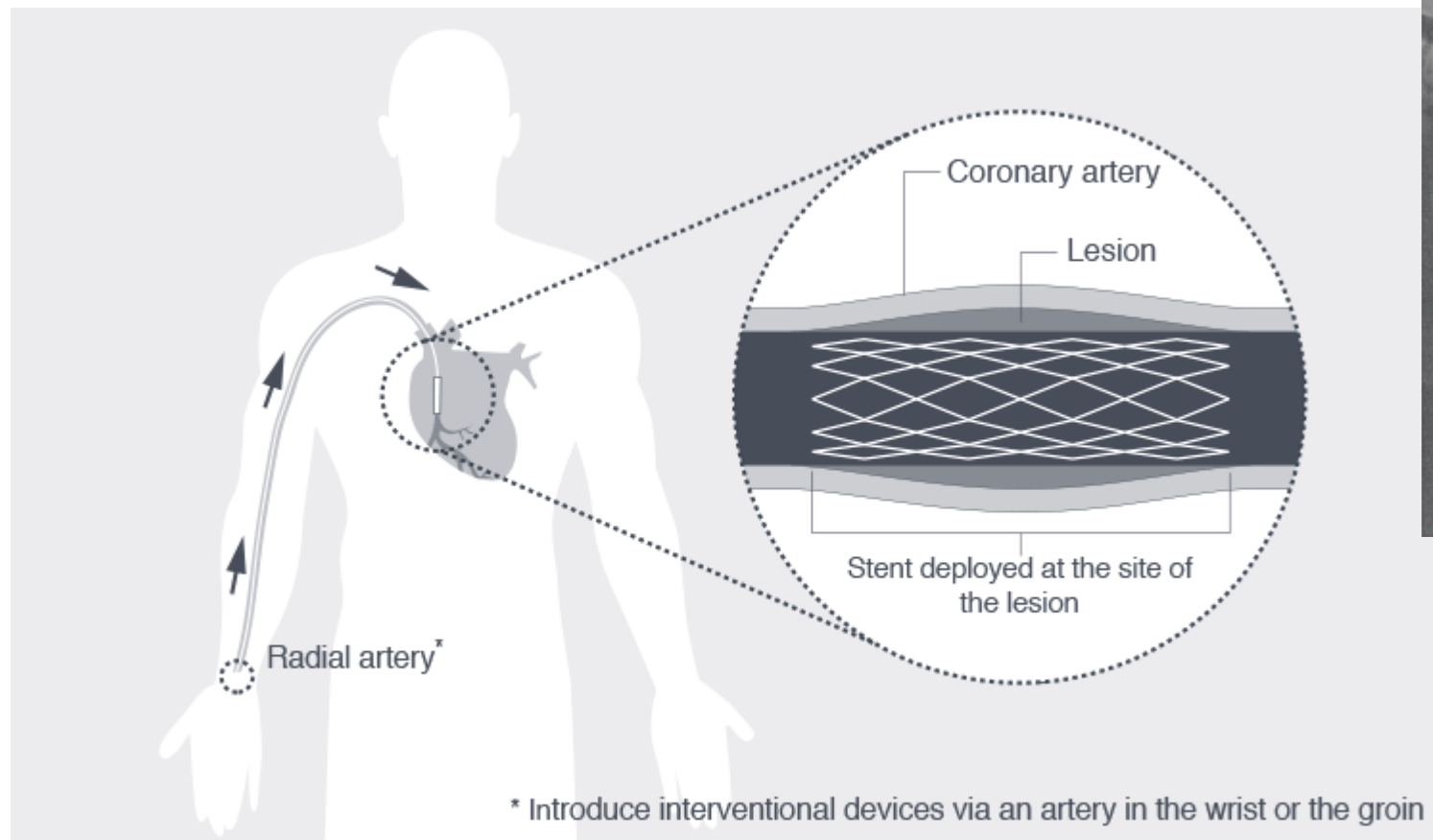
- Clinical Field: Cardiovascular Intervention
- Investigational Medical Device : Coronary Stent
- Study Design: Observational study (Registry), single arm, open label, 5 majors timepoints : Screening, Baseline, Procedure, 3 Months Follow-Up, 1 Year Follow-Up
- Primary endpoint: Validate Efficacy and Safety: Composite Endpoint of different SAE up to 1 year after procedure (i.e. TLF = Cardiac Death, TV related to MI and CD-TLR).
- Secondary endpoint: exploratory analysis
- Status: FPI in 2015, DBL 2019, N = 37.198, 378 sites, 50 countries

■ Limitations

- Global registry, observational study, include all kind of subject, no randomization, subjects treated as per hospital standard of care or PI's preferences.

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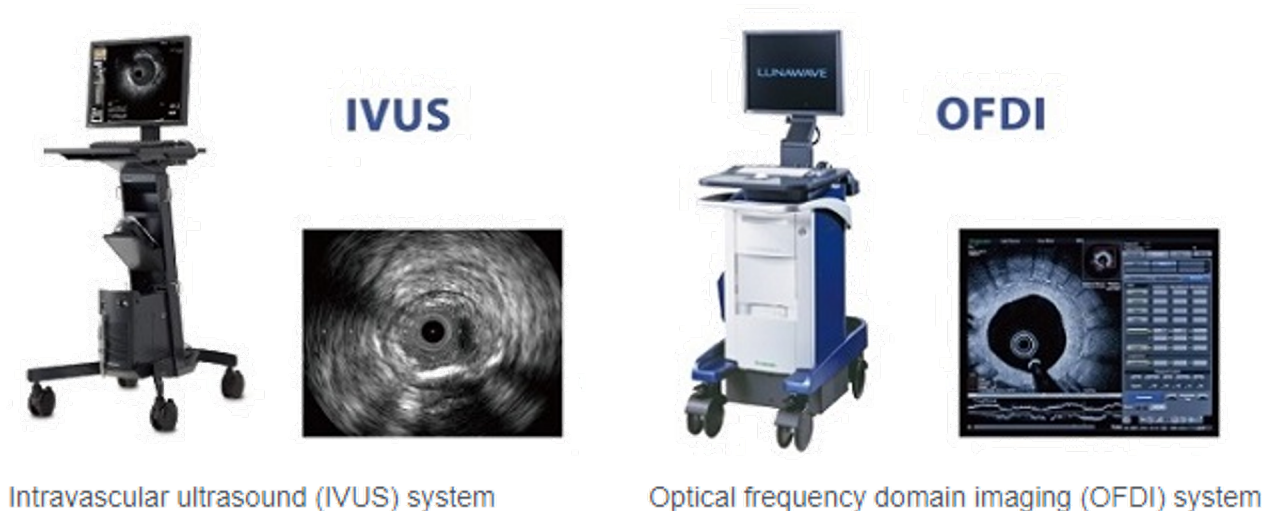
- Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?



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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Description



Imaging systems based on ultrasound or optical technology optimize procedures and support operators by acquiring luminal surface and cross-sectional images of blood vessels during PCI or PPI.

→ Used in 4.6% of the procedure.

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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

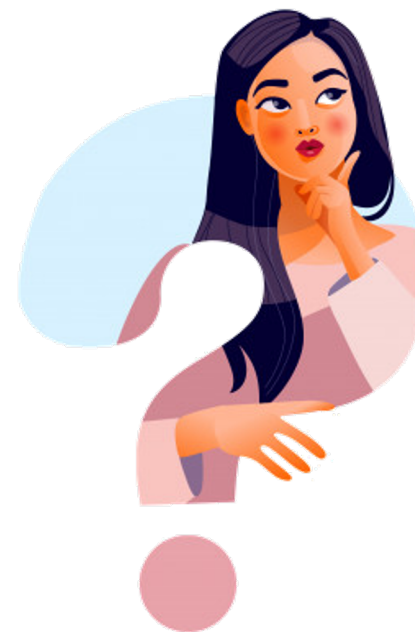
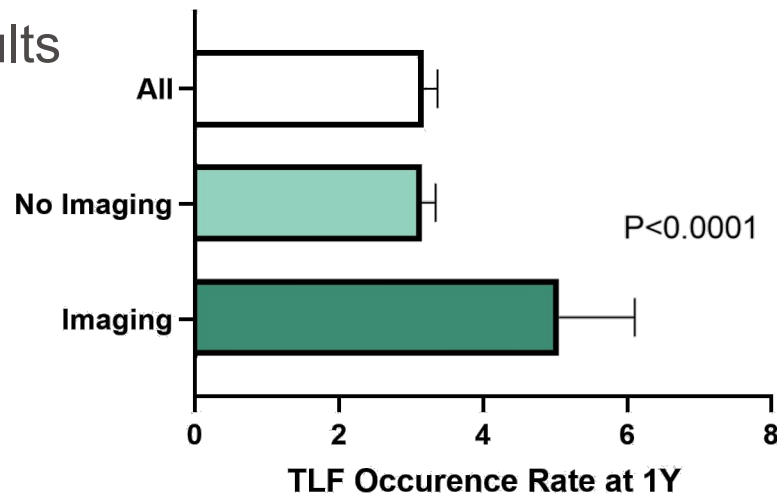
- Hypothesis

As imaging systems optimize procedures settings, we expect less complications and better outcome 1 year after the procedure.

X = Imaging Uses (Y/N)

Y = TLF at 1 year (Y/N)

- Results



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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Possible explanation

Imaging systems is mainly used to treat more complex cases (based on subject or lesion characteristics).

- Adjustment

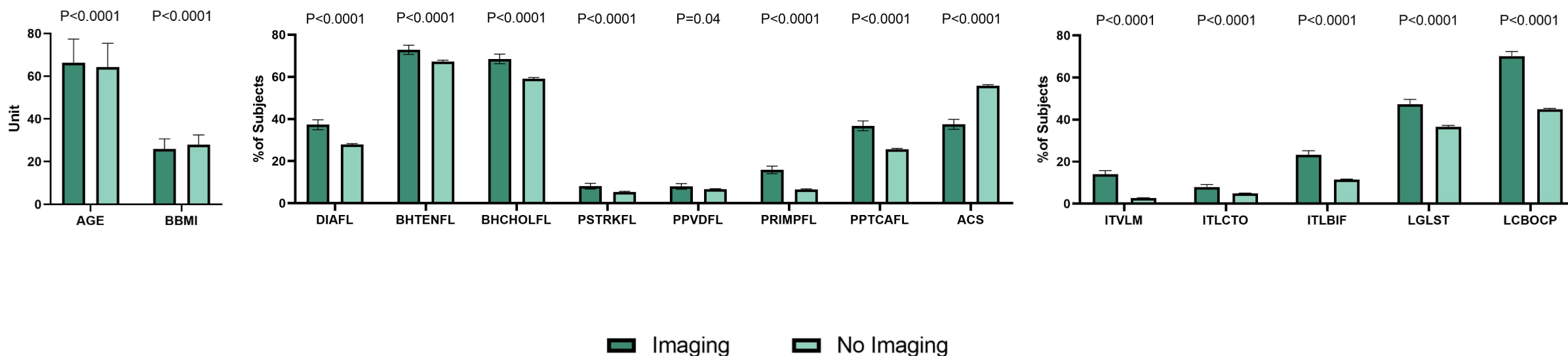
X = Imaging Uses (Y/N)

Y = TLF at 1 year (Y/N)

U = Set of Covariates to be defined

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- **Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?**
 - Check for imbalances between control and treatment group



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- **Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?**
 - Check for imbalances between control and treatment group

Variable	Effect	Number of Observations Read	Number of Observations Used	% of Observations Used	Odds Ratio Estimate	Lower 95% Confidence Limit for Odds Ratio	Upper 95% Confidence Limit for Odds Ratio	Pr > Chi-Square
AGE	AGE	35389	35389	✓ 100.0%	1.017	1.012	1.021	<.0001
BBMI	BBMI	35389	28446	✗ 80.4%	0.898	0.886	0.910	<.0001
DIAFL	DIAFL Y vs N	35389	34780	✓ 98.3%	1.539	1.388	1.706	<.0001
BHTENFL	BHTENFL Y vs N	35389	31990	⚠ 90.4%	1.302	1.163	1.457	<.0001
BHCHOLFL	BHCHOLFL Y vs N	35389	30843	⚠ 87.2%	1.503	1.349	1.675	<.0001
PSTRKFL	PSTRKFL Y vs N	35389	32847	⚠ 92.8%	1.552	1.281	1.879	<.0001
PPVDFL	PPVDFL Y vs N	35389	32200	⚠ 91.0%	1.222	1.014	1.473	0.0356
PRIMPFL	PRIMPFL Y vs N	35389	34628	✓ 97.8%	2.659	2.312	3.058	<.0001
PPTCAFL	PPTCAFL Y vs N	35389	32965	⚠ 93.2%	1.690	1.523	1.876	<.0001
ACS	ACS Y vs N	35389	35369	✓ 99.9%	0.474	0.428	0.525	<.0001
ITVLM	ITVLM Y vs N	35389	35389	✓ 100.0%	6.027	5.165	7.034	<.0001
ITLCTO	ITLCTO Y vs N	35389	35389	✓ 100.0%	1.664	1.381	2.005	<.0001
ITLBIF	ITLBIF Y vs N	35389	35389	✓ 100.0%	2.348	2.084	2.645	<.0001
LGLST	LGLST Y vs N	35389	35343	✓ 99.9%	1.609	1.457	1.777	<.0001
LCBOCP	LCBOCP Y vs N	35389	35389	✓ 100.0%	2.893	2.598	3.223	<.0001

→ How to deal with missing values ?

■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Logistic Regression Model

→ After adjustment for baseline differences, the impact of additional imaging on TLF occurrence at 1Y is not statistically significant anymore (p=0.43)!

Number of Observations Read		35389	TLF1Y		Y	1135
Number of Observations Used		35389			N	34254

Effect	DF	Wald Chi-Square	Pr > Chi-Square	Odds Ratio Estimate	Lower 95% Confidence Limit for Odds Ratio	Upper 95% Confidence Limit for Odds Ratio
Intercept	1	292.8289	<.0001			
IMAGE Y vs N	1	0.6185	0.4316	1.103	0.864	1.410
AGE	1	45.6225	<.0001	1.020	1.014	1.026
BBMI	1	0.8080	0.3687	0.993	0.979	1.008
DIAFL Y vs N	1	27.1735	<.0001	1.410	1.239	1.605
BHTENFL Y vs N	1	1.2212	0.2691	0.925	0.806	1.062
BHCHOLFL Y vs N	1	0.2275	0.6334	0.969	0.853	1.102
PSTRKFL Y vs N	1	5.3868	0.0203	1.295	1.041	1.612
PPVDFL Y vs N	1	16.0479	<.0001	1.492	1.227	1.815
PRIMPFL Y vs N	1	50.4779	<.0001	1.889	1.585	2.251
PPTCAFL Y vs N	1	35.9979	<.0001	1.495	1.311	1.705
ACS Y vs N	1	24.9200	<.0001	1.376	1.214	1.560
ITVLM Y vs N	1	48.3981	<.0001	2.258	1.795	2.840
ITLCTO Y vs N	1	0.2018	0.6533	1.065	0.809	1.401
ITLBIF Y vs N	1	12.4154	0.0004	1.347	1.141	1.589
LGLST Y vs N	1	0.0056	0.9402	1.005	0.886	1.140
LCBOCP Y vs N	1	16.0442	<.0001	1.299	1.143	1.476

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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Compute the propensity scores – Estimate the propensity model
Method : include all predictors, Stepwise Selection, SLE=0.05, SLS=0.05

Number of Observations Read	35389	IMAGE	Y	1642
Number of Observations Used	35389		N	33747

Step	Effect Entered	DF	Number of Effects In Model	Score Chi-Square	Pr > Chi-Square	Effect	Odds Ratio Estimate	Lower 95% Confidence Limit for Odds Ratio	Upper 95% Confidence Limit for Odds Ratio
1	ITVLM	1	1	662.3452	<.0001	ITVLM Y vs N	3.849	3.237	4.577
2	LCBOCP	1	2	333.1108	<.0001	LCBOCP Y vs N	2.232	1.989	2.505
3	BBMI	1	3	272.6651	<.0001	BBMI	0.876	0.864	0.889
4	ACS	1	4	195.5462	<.0001	ACS Y vs N	0.549	0.493	0.611
5	PRIMPFL	1	5	124.5823	<.0001	PRIMPFL Y vs N	1.945	1.671	2.265
6	BHCHOLFL	1	6	102.3030	<.0001	BHCHOLFL Y vs N	1.591	1.421	1.782
7	DIAFL	1	7	48.6366	<.0001	DIAFL Y vs N	1.441	1.290	1.609
8	PPTCAFL	1	8	22.4584	<.0001	PPTCAFL Y vs N	1.300	1.163	1.452
9	LGLST	1	9	19.2665	<.0001	LGLST Y vs N	1.260	1.134	1.400
10	ITLBIF	1	10	17.5167	<.0001	ITLBIF Y vs N	1.333	1.165	1.526
11	BHTENFL	1	11	7.7020	0.0055	BHTENFL Y vs N	1.190	1.056	1.342
12	PPVDFL	1	12	5.5940	0.0180	PPVDFL Y vs N	0.787	0.645	0.960

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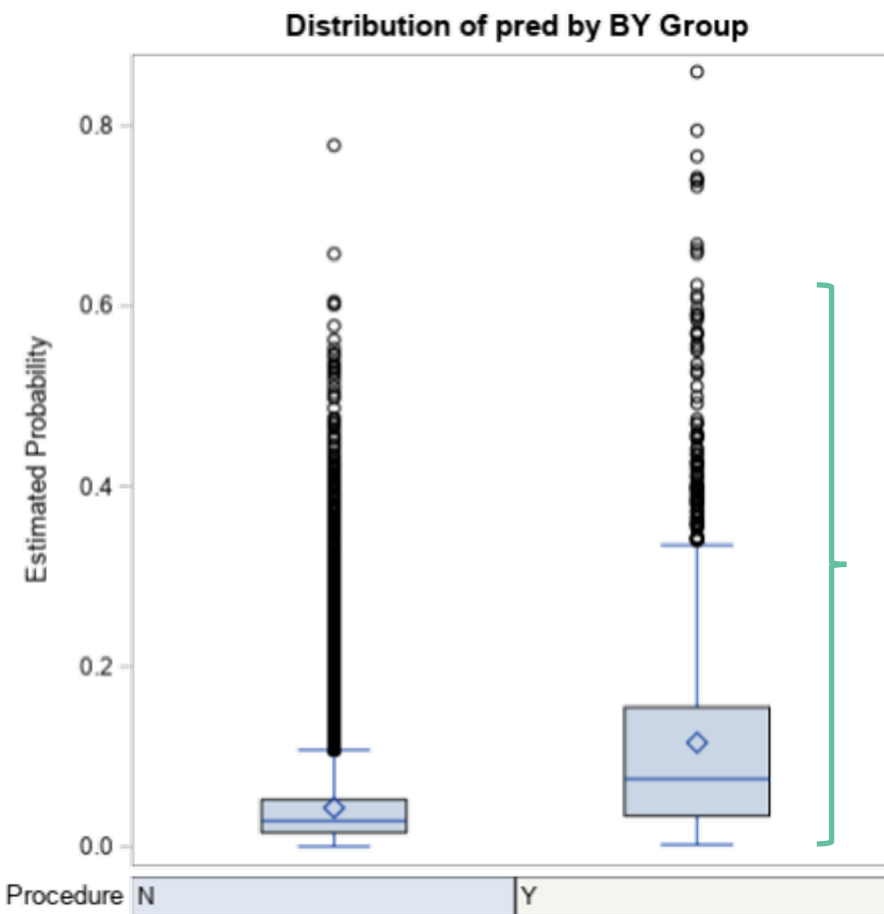
■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Compute the propensity scores
Predict individual propensity score

```
proc logistic data=psm.analysis_image_imputed ;  
  
class IMAGE (ref="N") DIAFL (ref='N') BHTENFL (ref='N')  
BHCHOLFL (ref='N') PSTRKFL (ref='N') PPVDFL (ref='N')  
PRIMPFL (ref='N') PPTCAFL (ref='N') ACS (ref='N')  
ITVLM (ref='N') ITLCTO (ref='N') ITLBIF (ref='N')  
LGLST (ref='N') LCBOP (ref='N')  
/param = ref;  
model /*X*/ IMAGE =  
/*N*/ AGE BBMI  
/*C*/ DIAFL BHTENFL BHCHOLFL PSTRKFL PPVDFL PRIMPFL  
PPTCAFL ACS ITVLM ITLCTO ITLBIF LGLST LCBOP  
/ selection=stepwise sle=0.05 sls=0.05 ;  
Output out=ps predicted=pred;  
run;
```

Note: PS = probability

→ all values are between 0 and 1.



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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis
Method: Logistic Regression with adjustment

```
/* PS ANALYSIS - OPTION A */  
/* LOGISTIC REGRESSION MODEL USING PS IN THE MODEL */  
  
proc logistic data=ps ;  
class /*Y*/ TLF1Y (ref='N') IMAGE (ref='N') /param = ref;  
model /*Y*/ TLF1Y = IMAGE PRED /*PS - X on U*/ ;  
run;
```

➔ After adjustment for PS, the impact of additional imaging on TLF occurrence at 1Y is not statistically significant anymore (p=0.75)!

Number of Observations Read		35389	TLF1Y		Y	1135
Number of Observations Used		35389			N	34254
Effect	DF	Wald Chi-Square	Pr > Chi-Square	Odds Ratio Estimate	Lower 95% Confidence Limit for Odds Ratio	Upper 95% Confidence Limit for Odds Ratio
Intercept	1	9484.3451	<.0001			
IMAGE Y vs N	1	0.0978	0.7545	1.041	0.808	1.342
pred	1	149.9468	<.0001	89.447	43.571	183.626

■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis
Method: Stratification

```
/* PS ANALYSIS - OPTION B      */
/* USING DECILES OF PS        */

proc rank data=ps groups=10 out=ranked;
var pred;
ranks decile;
run;

proc freq data = ranked ;
tables decile*tlfly*IMAGE / cmh expected chisq;
run;
```

➔ After Stratification for PS, the impact of additional imaging on TLF occurrence at 1Y is not statistically significant anymore (p=0.17)!

Summary Statistics for TLF1Y by IMAGE
Controlling for decile

Cochran-Mantel-Haenszel Statistics (Based on Table Scores)				
Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	1.8599	0.1726
2	Row Mean Scores Differ	1	1.8599	0.1726
3	General Association	1	1.8599	0.1726

Common Odds Ratio and Relative Risks				
Statistic	Method	Value	95% Confidence Limits	
Odds Ratio	Mantel-Haenszel	1.1813	0.9299	1.5006
	Logit	1.2496	0.9823	1.5897
Relative Risk (Column 1)	Mantel-Haenszel	1.0104	0.9945	1.0266
	Logit	1.0009	0.9894	1.0125
Relative Risk (Column 2)	Mantel-Haenszel	0.8659	0.7055	1.0628
	Logit	0.8234	0.6718	1.0093

Breslow-Day Test for Homogeneity of Odds Ratios	
Chi-Square	8.5373
DF	9
Pr > ChiSq	0.4810

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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis

Method: Matching 1:X using Greedy Nearest Neighbor Matching Option

```
/* PS ANALYSIS - OPTION C      */  
/* MATCHING PS 1:X             */
```

```
proc psmatch data=psm.analysis_image_imputed region=treated;  
class IMAGE DIAFL BHTENFL BHCHOLFL PPVDFL PRIMPFL PPTCAFL ACS ITVLM ITLBIF LGLST LCBOCP ;  
psmodel IMAGE(Treated='Y')= BBMI DIAFL BHTENFL BHCHOLFL PPVDFL PRIMPFL PPTCAFL ACS ITVLM ITLBIF LGLST LCBOCP ;  
match distance=lps method=greedy(k=1) caliper=1.0  
weight=none;  
output out(obs=match)=OutEx matchid=_MatchID;  
run;
```

Propensity Score Information											
Observations	Treated (IMAGE = Y)					Control (IMAGE = N)					Treated - Control
	N	Mean	Standard Deviation	Minimum	Maximum	N	Mean	Standard Deviation	Minimum	Maximum	Mean Difference
All	1642	0.1154	0.1190	0.0022	0.8600	33747	0.0430	0.0468	0.0002	0.7783	0.0724
Region	1642	0.1154	0.1190	0.0022	0.8600	33674	0.0431	0.0468	0.0017	0.7783	0.0723
Matched	1642	0.1154	0.1190	0.0022	0.8600	1642	0.1136	0.1118	0.0022	0.7783	0.0018

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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

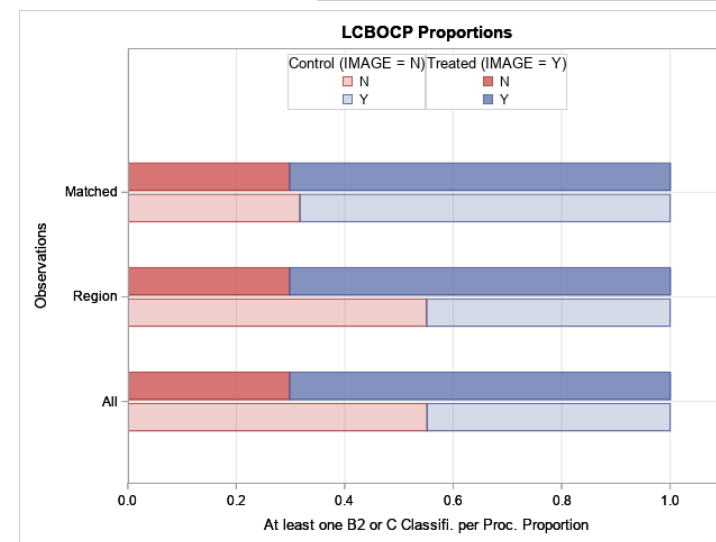
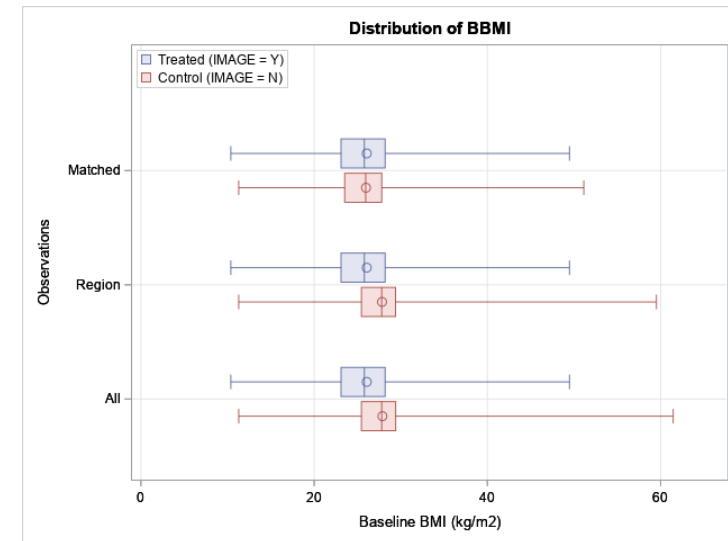
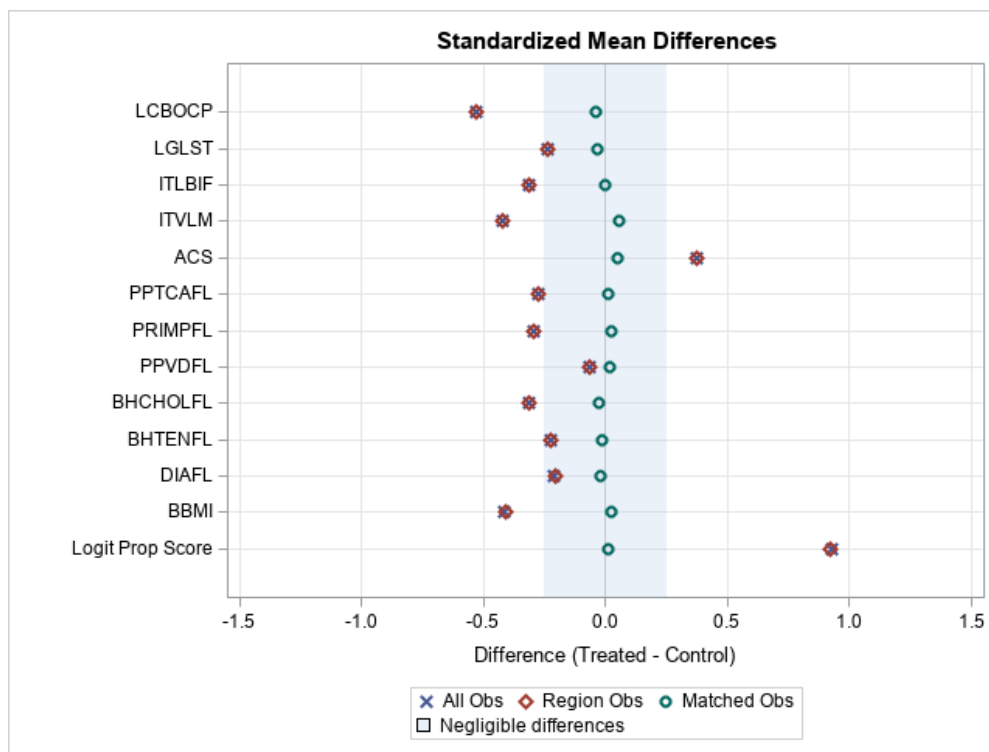
- Integrate the propensity score in the analysis

Method: Matching 1:X using Greedy Nearest Neighbor Matching Option

	USUBJID	DIAFL	BHCHOLFL	BHTENFL	BBMI	PPVDFL	PPTCAFL	PRIMPFL	ACS	LCBOCP	LGLST	ITVLM	ITLBIF	IMAGE	_PS_	_MATCHWGT_	_MatchID
1	eU-T123E2_EU-602-011	Y	Y	Y	15.429803688	N	Y	Y	N	Y	N	Y	Y	Y	0.8599607022	1	1
2	eU-T123E2_EU-653-546	Y	Y	Y	19.591836735	Y	Y	Y	N	Y	Y	Y	Y	N	0.7782897588	1	1
3	eU-T123E2_EU-583-005	Y	Y	Y	20.661157025	N	Y	Y	N	Y	Y	Y	Y	Y	0.794763607	1	2
4	eU-T123E2_EU-654-174	Y	Y	Y	25.951557093	N	Y	Y	N	Y	Y	Y	Y	N	0.6578376223	1	2
5	eU-T123E2_EU-603-120	N	N	Y	15.662554078	N	Y	Y	N	Y	Y	Y	Y	Y	0.7660260729	1	3
6	eU-T123E2_EU-653-152	Y	Y	N	24.609375	N	Y	Y	N	Y	N	Y	Y	N	0.6048353359	1	3
7	eU-T123E2_EU-307-123	Y	Y	Y	21.484375	N	Y	Y	Y	Y	N	Y	Y	N	0.6021344685	1	4
8	eU-T123E2_EU-594-013	Y	Y	Y	20.904195011	N	N	Y	N	Y	Y	Y	Y	Y	0.7425853559	1	4
9	eU-T123E2_EU-307-159	Y	Y	Y	24.221453287	Y	Y	Y	N	Y	N	Y	Y	N	0.6014865118	1	5
10	eU-T123E2_EU-595-006	Y	Y	Y	21.203155819	Y	Y	Y	N	Y	Y	Y	Y	Y	0.739324744	1	5
...																	
3275	eU-T123E2_EU-029-353	N	N	N	32.979591837	N	N	N	Y	N	N	N	N	N	0.0041648126	1	1638
3276	eU-T123E2_EU-057-116	N	N	N	34.729638859	N	N	N	Y	N	Y	N	N	Y	0.0041635108	1	1638
3277	eU-T123E2_EU-028-072	N	N	N	33.376654064	N	N	N	Y	N	N	N	N	N	0.0039524335	1	1639
3278	eU-T123E2_EU-436-080	N	N	N	41.617122473	N	N	N	Y	Y	N	N	Y	Y	0.0039517039	1	1639
3279	eU-T123E2_EU-049-040	N	Y	Y	51.132213294	N	Y	N	N	N	Y	N	Y	N	0.0028422489	1	1640
3280	eU-T123E2_EU-066-014	N	N	Y	37.202380952	N	N	N	Y	N	N	N	N	Y	0.0028389824	1	1640
3281	eU-T123E2_EU-066-116	N	N	Y	40.562466198	N	N	N	Y	N	Y	N	N	Y	0.0022946522	1	1641
3282	eU-T123E2_EU-852-193	N	N	N	39.246467818	N	N	N	Y	N	Y	N	N	N	0.0022942597	1	1641
3283	eU-T123E2_EU-028-170	N	N	Y	39.06719835	N	N	N	Y	N	N	N	N	N	0.0022194277	1	1642
3284	eU-T123E2_EU-436-061	N	Y	Y	42.567322787	N	N	N	Y	N	N	N	N	Y	0.002221769	1	1642

■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis –
Check if propensity score matching reduced the imbalances



■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis
Estimate treatment effect on matched pairs (1:1)

```
proc sort data=OutEx ; by usubjid ; run ;

data OutExTLF ;
merge OutEx psm.analysis_image_imputed (keep = usubjid tlfly);
by usubjid ;
run ;

proc freq data=OutExTLF ;
table tlfly*image / nopercnt norow chisq ;
run;
```

The FREQ Procedure

Frequency Col Pct	Table of TLF1Y by IMAGE			
	TLF1Y(Target Lesion Failure up to 1Y)	IMAGE(Imaging Performed at Index Procedure)		
		N	Y	Total
N		1557 94.82	1559 94.95	3116
Y		85 5.18	83 5.05	168
Total		1642	1642	3284
Frequency Missing = 32105				

Statistics for Table of TLF1Y by IMAGE

Statistic	DF	Value	Prob
Chi-Square	1	0.0251	0.8741
Likelihood Ratio Chi-Square	1	0.0251	0.8741
Continuity Adj. Chi-Square	1	0.0063	0.9369
Mantel-Haenszel Chi-Square	1	0.0251	0.8742
Phi Coefficient		-0.0028	
Contingency Coefficient		0.0028	
Cramer's V		-0.0028	

Odds Ratio and Relative Risks

Statistic	Value	95% Confidence Limits	
Odds Ratio	0.9752	0.7149	1.3303
Relative Risk (Column 1)	0.9876	0.8471	1.1515
Relative Risk (Column 2)	1.0127	0.8656	1.1848

Sample Size = 3284
Frequency Missing = 32105

■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Integrate the propensity score in the analysis

Method: Adjustment by Inverse probability of treatment weighting

```

/* PS ANALYSIS - OPTION D      */
/* IPTW with ATT weights      */

data ips;
  set ps ;
  if image = "N" then weight1 = 1/(1-pred);
  if image = "Y" then weight1 = 1/(pred);
run;

data ips_use;
  set ips;
  if weight1 > 32.49160 then delete; *Exclude 1% upper cases;
  if weight1 < 1.00375 then delete; *Exclude 1% lower cases;
  logit_ps = log(pred/(1-pred));
run;

proc causaltrt data = ips_use METHOD=IPWR ATT;
  class image tlfly &class;
  psmodel image (REF="N") = &class &cont;
  model tlfly = / DIST=BIN;
  ods output CausalEffects= CausalEffects_ATT_IPWR;
run;

```

Response Profile		
Ordered Value	TLF1Y	Total Frequency
1	Y	1114
2	N	33567

PROC CAUSALTRT is modeling the probability that TLF1Y='Y'.

Treatment Profile		
Ordered Value	IMAGE	Total Frequency
1	Y	1288
2	N	33393

PROC CAUSALTRT is modeling the probability that IMAGE='Y'.

	Parameter	Level	OR	OR_LOW	OR_UP	ProbZ
1	POM	Y	1.0550323485	1.0421380139	1.0680862243	<.0001
2	POM	N	1.056997387	1.0462088516	1.0678971742	<.0001
3	ATT		0.998140924	0.9825650733	1.0139636867	0.8166

IPTW model (ATT)

The CAUSALTRT Procedure

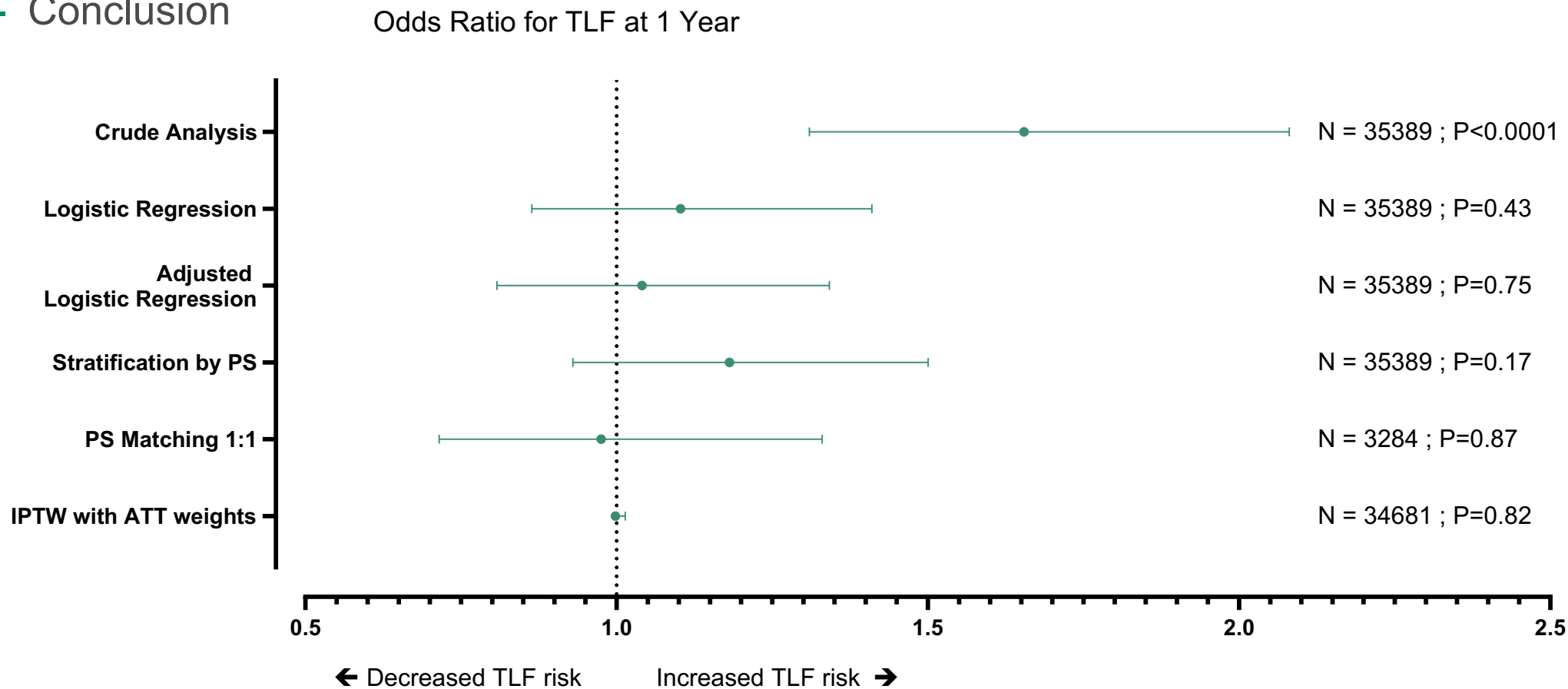
Model Information	
Data Set	WORK.IPS_US
Distribution	Binomial
Estimation Method	IPW
Treatment Variable	IMAGE
Outcome Variable	TLF1

Number of Observations Read	34681
Number of Observations Used	34681

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■ Sub Analysis : Impact of Intravascular Imaging on TLF occurrence up to 1 Year after the procedure ?

- Conclusion



Conclusion

Conclusion

■ Advantages

- Large number of confounders can be considered to calculate PS
- Separation of confounder adjustment and outcome analyses
- Multi-step process with many alternatives and options

■ Limitations

- Groups are balanced in all observed covariates (extra confounding variable not recorded?)
- Require statistical expertise to define population selection, handling of missing values, methodology to be applied, assessing success of matching, etc.
- Selective loss of study participants - May need to exclude the unmatched patients.
- May need additional sensitivity analysis
- No estimation of the effects of the confounders or interactions



Thank you !

References

- Rosenbaum PR, Rubin DB. *The central role of the propensity score in observational studies for causal effects*. Biometrika. 1983; 70:41–55.
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- Austin PC. *The use of propensity score methods with survival or time-to-event outcomes: reporting measures of effect similar to those used in randomized experiments*. Stat Med. 2014 Mar 30; 33(7):1242-58.