Effect of Multidisciplinary Team (MDT) Centered on Pregnant Women with Pulmonary Hypertension on Treatment and Outcomes of Pregnancy

Wenjie Chen
Second Xiangya Hospital of Central South University
Jun Luo
Second Xiangya Hospital of Central South University
Jingyuan Chen
Second Xiangya Hospital of Central South University
Yusi Chen
Second Xiangya Hospital of Central South University
Zilu Li
Second Xiangya Hospital of Central South University
Haihua Qiu
Second Xiangya Hospital of Central South University
Jiang Li (lijiangcs@csu.edu.cn)
Second Xiangya Hospital of Central South University

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Abstract

Background

The importance of multidisciplinary team (MDT) centered on pregnant women with pulmonary hypertension (PH) has been highlighted. However, rare studies have explored the its effects on pregnancy outcomes. This study seeks to investigate whether and how the MDT has an effect on the treatment and outcomes of PH pregnant women.

Methods

A pre- and post-intervention study was conducted based on an interrupted time series design to compare the treatment and outcomes of patients with PH before (pre-MDT) and after (post-MDT) implementation of the MDT. PH was defined as pulmonary artery systolic pressure (sPAP) ≥ 40 mmHg measured by echocardiography or right heart catheterization and sPAP at 40–60mmHg and over 60mmHg was defined as mild and severe PH, respectively. All results were analyzed by T-tests, Chi square tests or Fisher exact test and two-sided p-value < 0.05 was set to be statistically significant.

Results

149 pregnancies were found in 143 women with PH. Overall, 46 pregnancies were elective abortions, remaining 49 and 54 pregnancies completing delivery in the pre-MDT group and post-MDT group, respectively. Five (10.2%) mother and seven (8.6%) neonatal died in the former, while no maternal deaths but 1.9% neonatal death occurred in the latter. In subgroup analysis, maternal and fetal/neonatal complications were higher in patients with severe PH and New York Heart Association (NYHA) functional class III/IV and all maternal deaths occurred in class III/IV women. In pre-MDT and post-MDT groups, there were 8 and 22 pregnant women receiving the pulmonary-specific therapy and completing delivery, respectively. The percentage of heart failure and urgent cesarean of pre-MDT group was higher than the post-MDT group (30.6% vs. 12.9%, p = 0.02; 40.8% vs. 14.8%, p = 0.01, respectively).

Conclusion

Implementing the MDT decreased the rate of urgent cesarean section and heart failure in patients with PH and no maternal death occurred in the post-MDT group. Pregnant women with severe PH and NYHA FC III/IV might have poor prognosis, whereas the use of pulmonary-specific therapy might improve outcomes of pregnancy in PH.

Introduction

Pulmonary hypertension (PH) has been reported as a pathophysiological disorder that is characterized by an increase of pulmonary arterial pressure (PAP) and results in right heart failure and death[1]. The 6th World Symposium on Pulmonary Hypertension (WSPH) in 2018 updated PH classification and divided PH into five groups in accordance with their pathogenesis and treatment strategies: (1) pulmonary arterial hypertension (PAH; group 1 PH); (2) PH arising from left heart disease (LHD-PH; group 2 PH); (3) PH caused by lung diseases and/or hypoxia (group 3 PH); (4) PH due to pulmonary artery obstructions (group 4 PH); (5) PH with unclear and/or multifactorial mechanisms (group 5 PH)[2].

Pregnancy with any type of PH has been found as a potential disaster as limited therapies and poor pregnancy outcomes with the maternal mortality rate of a horrible 30–56%[3, 4]. Thus, a consensus has been reached women with PH (especially PAH) should adopt effective contraception and early termination of accidental pregnancy [5–8]. However, the risk of pregnancy termination in patients with PH is higher than in the general population, and pregnancy termination is recommended at experienced PH centers[9].

Over the last decade, PAH-specific therapies, consisting of prostaglandin analogue (e.g., epoprostenol) and phosphodiesterase 5 inhibitors (e.g., sildenafil), have been used for the treatment of China's pregnant women with PAH[10, 11]. However, the recent studies and meta-analysis suggested that the maternal mortality rate still account for 12%-20% in pregnant PH patients, and most maternal deaths occur in the early postpartum period[11–13]. Accordingly, improving the pregnant prognosis in women with PH is still challenging and usually involves the combination of multiple disciplines. To better care for pregnant women with PH, in December 2012, the multidisciplinary term (MDT) centered on women with PH was established at our hospital. Although the importance of the MDT has been already highlighted by guidelines and clinic experience, whether and how the MDT approach affects treatment and outcomes of pregnant women with PH remains unclear [14, 15].

To verify the effectiveness of the MDT model, a longitudinal analysis was conducted on the characteristics, treatment and outcomes of cared patients by our MDT, and patients treated before and after the establishment of this team were compared.

Methods

The retrospective study gained an approval from the review board of the Second Xiangya Hospital of Central South University. The electronic medical records of 143 pregnant women with PH (six had two pregnancies) admitted into our hospital from January 2004 to June 2020 were reviewed. The PAP was evaluated using either echocardiography or right heart catheterization (RHC). RHC has been recognized as the “gold standard” for the diagnosis of PH (mPAP > = 25mmHg). The echocardiography, as a noninvasive method, has been confirmed as an accurate method of evaluating PAP[16]. In this study, the patients with pulmonary arterial systolic pressure (sPAP) of higher than 35 mmHg were considered as PH, and the patients with sPAP at 35-60mmHg and over 60mmHg were defined as mild and severe PH, respectively. Furthermore, the baseline characteristics, diagnosis and treatment plan, maternal and infant outcomes and follow-up information of all patients were extracted.

To better care for pregnant women with PH, the multidisciplinary team (MDT) centered on pregnant women with PH, in December 2012, was established in our hospital. One month (from December 1 to 30, 2012) was set as a “run-in” period, and the information regarding MDT in our hospital was disseminated. Thus, the data fell into pre-MDT (01/2004–11/2012) and post-MDT (1/2013–6/2020) groups. The MDT consisted of obstetrician, respiratory specialist, cardiologist, anesthesiologist, rheumatic immunologist, cardiac surgeon, neonatologist, as well as critical care specialist. Figure 1 illustrates the treatment strategy of the MDT.

The aim of this study was to conduct a retrospective study and evaluate the effect of the introduction of a MDT program on treatment and outcomes in pregnant women with PH, whereas some unmeasured confounders (e.g., the advance of medicine and technology) would be unlikely to avoid.

The following data was collected by our team. The pregnant basic information consisted of age, New Yorker Heart Association functional class (NYHA FC). The characteristics of PH involved etiology, echocardiography and PAP. The obstetric characteristics covered parity, time and mode of deliver, anesthetic management, as well as baby weight. Patients would be followed up by phone for up to 3 months if available.

All statistical analysis was conducted with IBM SPSS (Version 25) software. Continuous variables were expressed as mean ± standard deviation or median with range. Pre- and post-MDT patients were compared through t-tests and Wilcoxon rank sum text for continuous variables, as well as through Chi square tests and Fisher exact test for categorical variables. The subgroup analysis of severity of PH and level of NYHA FC was conducted to explore their effects on material and fetal/neonatal outcomes. For all analyses, a two-sided p-value < 0.05 showed statistical significance.

Results

Analysis of Baseline Characteristics in Two Groups

149 pregnancies occurred in 143 women with PH, and 46 pregnancies were elective abortions that were mostly performed before 20 weeks of gestation, thus leaving 49 pregnancies and 54 pregnancies completing delivery for the statistical analysis in the pre-MDT group and in the post-MDT group, respectively. The rate of therapeutic abortion in the post-MDT group was significantly higher than that of the pre-MDT group (19.7% vs. 38.6% vs.; p = 0.014). Table 1 lists the characteristics of the pregnant women with PH completing delivery.

A significant difference in the median age of pregnant women between the pre-MDT group and the post-MDT group was identified (25; range [20,44] vs. 28; range [18,40], p = 0.01). The rate of regular follow-up for the pregnant women with PH increased by around 50%, from 53.0% of the pre-MDT to 79.6% of the post-MDT in our hospital (p < 0.005). However, for median gestational age at delivery, no significant difference was found in the two groups (37, range [31,42] vs. 36, range [27,40], p = 0.275). Most women with PH were diagnosed as congenital heart disease-associated PAH (CHD-PAH) in both pre-MDT and post-MDT groups (n = 30/49, 61.2% vs. n = 33/54, 61.2%).

The post-MDT group had more numbers and a higher percentage (n = 34, 63%) of pregnant women with severe PH, compared with (n = 25, 51.0%) the pre-MDT group. NYHA FC I, II and IV were found to be similar in two groups, whereas the proportion of NYHA FC III in the post-MDT group increased significantly (18.4% vs. 37%, p = 0.03).

Comparison of Management in Two Groups

Table 2 lists the detail of management for women with PH in pre-MDT and post-MDT groups. 33 and 37 pregnant women with group 1 PH (PAH) were indicated to undergo PAH-specific therapy during pregnancy. In the pre-MDT group, only 8/33 (24.2%) pregnant women with PAH underwent PAH-specific therapy before delivery and majority (n = 8/9) of the above only received monotherapy. After the MDT was established, 22/37(59.5%) received PAH-specific therapy, and 10 of 22 (45.5%) underwent combination therapy (e.g., sildenafil or tadanafil combined with iloprost or treprostinil).

Except for a patient (in the pre-MDT group) missing delivery information, detailed birth records were collected for 102 patients. Both groups of pregnant women delivered primarily through cesarean section (95.8% vs. 98.1%). However, there was significant difference in the two groups in anesthesia. 39.1% of pregnancies delivered through cesarean section under general anesthesia, and 60.9% (n = 28/46) delivered under chosen epidural or spinal or epidural-spinal anesthesia in the pre-MDT group, whereas general anesthesia was found as the major anesthesia method (71.7%) of cesarean in the post-MDT group. Furthermore, in the pre-MDT group, more pregnant women with PH (n = 20/48, 41.6%) who had an unstable hemodynamics required emergent cesarean section for pregnancy termination compared with 14.8% (n = 8/54) patients in the post-MDT group (p = 0.001).

Maternal and Fetal/Neonatal Outcomes in Two Groups and Subgroup Analysis

Table 3 lists the maternal and fetal/neonatal outcomes. Five pregnant women died, and all of them (n = 5/49, 10.2%) occurred in the pre-MDT groups within 2 weeks after delivery and were diagnosed as CHD-PAH. To be specific, two women had patent ductus arteriosus (PDA), one woman had atrial septal defect (ASD), and two women had ventricular septal defect (VSD). Table 4 lists the characteristics of dead pregnant women. In the post-MDT group, there was no death, and the incidence of heart failure also significantly decreased from 30.6 % of pre-MDT to 13.2% (p = 0.029). However, the preterm delivery significantly increased in the post-MDT group (34.7% vs. 5.6%, p = 0.034)

49 and 52 live births were found in pre-MDT and post-MDT groups, respectively, and there was a twin pregnancy in each group. The neonatal mortality rate of 8.2% (n = 6/49) was significantly higher in the pre-MDT group than the mortality rate of 1.9% (n = 1/52) in the post-MDT group (p = 0.034). Moreover, there were similar results of intrauterine growth restriction (IUGR) (32.6% vs. 13.5, p = 0. 022).

Figure2 (a) and Figure2 (b) indicate that the subgroup analyses were conducted by severity of PH and level NAHA FC, respectively. Maternal and fetal/neonatal complications were found to be higher in the severe PH group, and a significant difference was found in preterm delivery and low birth weight infants. The similar results were achieved in the subgroup of NYHA FC. All maternal deaths were found in NYHA FC III/IV women, in which the incidence of heart failure was significantly higher than that of pregnancy with NYHA FC I/II.

Discussion

In the management of pregnant women with PH, especially PAH, multidisciplinary collaboration has been repeatedly stressed by expert consensus and clinicians, whereas there have been rare comparative studies to determine the role and value of the MDT. Although the maternal mortality rate was as high as 10.2% in the pre-MDT group, there were no deaths after the implementation of the MDT in our hospital. As revealed by the above result, the MDT contributed to the reduction of maternal mortality, consistent with existing reports[15]. Our MDT was formed in December 2012, consisting of obstetrician, PH specialist, cardiologist, anesthesiologist, cardiac surgeon, neonatologist and critical care specialist, aiming at streamline treatments and improving maternofetal outcomes in pregnant women with PH (Fig. 1 to be modified), the MDT focused on and weighed the risks and benefits of continuing or terminating pregnancy and the life of mother and fetus, and make decisions timely. To determine whether and how MDT centered on pregnant women with PH affects the maternal treatment and outcomes, the first larger group was presented based on the comparison of the characteristics, treatments and outcomes of PH patients before and after the introduction of the MDT.

Therapeutic abortion and postpartum care

Changes in cardiovascular system during pregnancy and delivery lead to PH worsening in women with PH since their compensatory mechanisms for the changes may be inability[17]. Plasma volume and cardiac output (CO) will start to increase early in pregnancy and reach the peak around 32 gestational weeks at values 40-50% above pre-pregnancy values[18, 19]. Moreover, the second trimester has been generally confirmed as the earliest period of deterioration of heart function for pregnant women with PH[20]. Accordingly, consensus guidelines have recommended women with PH to avoid pregnancy, and the first trimester to terminate pregnancy is considered the safest time[9, 14]. After the MDT was established, the percentage of therapeutic abortion increased from 19.7% of pre-MDT to 38.4% (p = 0.014), accompanying with the decline in the rate of material mortality and cardiac complications. Notably, in PH patients, pregnancy termination may lead to pregnant death and should be performed at an experienced center[5, 21]. In women with PH, most pregnant deaths occur in the early postpartum period [11-13], which are largely caused by right heart (RV) failure and cardiovascular collapse[12, 22, 23]. In the group of this study, four women died of right heart (RV) failure in 2 weeks after delivery, and the another one died suddenly on the third day after being discharged from the hospital. As a result, the postpartum management was specially strengthened after the MDT was established. In general, pregnant women with PH, particularly associated with severe PH and NYHA FC III/IV, were carefully monitored in an intensive care unit (ICU) at least 24 h after delivery or after hemodynamics became stable.

Management of pregnant women with PH

Regular Follow-up and General Therapy

All women with PH insisting to continue pregnancy are required to monthly or weekly visit PH experts and obstetrics who evaluate pregnant heart function and PAP by echocardiograph. After the implementation of the MDT, the rate of regular clinic visits significantly increased to 79.6% associated with decline of material complications. In addition, pregnant patient with signs of worsening RV function, NYAH FC, or PAP was admitted into the hospital and received supported therapy including oxygen, diuretics and digoxin if indicated. Fig. 1 illustrates the treatment steps for women with PH after the implementation of the MDT at our PH center. Furthermore, severity of PH and NYHA FC might be correlated with adverse effects on the maternal and fetal/neonatal outcomes, as presented in Fig. 2 (a) (b). Thus, PAP/sPAP and NYHA FC were vital predictors for maternal prognosis.

Seven pregnant women (one in the pre-MDT group) with mitral valve stenosis underwent percutaneous balloon mitral valvuloplasty (PBMV) for severe lung congestion and dyspnea before delivery. Subsequently, the symptom rapidly relieved and successfully delivered. The risk and benefits of anticoagulants should be carefully evaluated. Prophylactic low molecular weight heparin (LMWH) might be considered for pregnant women with rest on bed.

Pulmonary-specific Therapy for Pregnancy with PAH

Not all pregnant women with PH underwent targeted drug therapy only for patients with group 1 PH (e.g., idiopathic, CHD, connective tissue disease-associated PAH). If the increase of PAP was evaluated through echocardiograph, pulmonary vascular specialist would conduct PAH-specific therapy for continued pregnancy women with PAH or hospitalization. Although there have been rare adequate, well-controlled studies of pulmonary-specific drugs for pregnant women, the data from retrospective literature suggested that pulmonary-specific therapy had improved maternal prognosis in pregnant PAH patients[15, 24]. The current PAH-specific drugs allowed for the treatment of pregnant women consist of prostaglandin analogue (e.g., epoprostenol, treprostinil and iloprost) and phosphodiesterase 5 inhibitors (e.g., sildenafifil and tadalafifil), whereas endothelin receptor antagonists (e.g., ambrisentan, bosentan, and macitentan) are contraindicated during pregnancy for potential teratogenic effects[7, 12].

A Japanese study suggested that among the patients with higher prepregnant PAP, the mPAP increased with the progress of pregnancy [25]. Thus, prepregnant sPAP can be referenced for initiating the PAH-specific therapy. In the group of this study, the sPAP of 6 of 8 pregnant women receiving PAH-specific therapy was evaluated over 60mmHg by echocardiogram in the pre-MDT group and 19 of 22 also over 60mmHg in the post-MDT group. Early use of pulmonary vasodilators has been found to prevent clinical worsening in nonpregnant patients with PAH[26, 27], and deterioration frequently occurs between weeks 20 and 24[20]. Thus, our team has usually recommended pregnant women to receive monotherapy for the control of PAP during the second trimester. In the perinatal period, if a pregnant woman has high-risk factors, the MDT will add prostaglandins or carry out early termination of pregnancy.

Mode and Timing of Delivery

Cesarean section may be the advisable mode of delivery in pregnancy complicated by PH compared with vaginal delivery[9, 10, 20]. There has always been a stubborn attitude to cesarean section in pregnant women with PH. Although 5 pregnant women with cesarean section died after delivery in the pre-MDT group, 4/5 deaths were severely unstable hemodynamics or obstetric indication. Moreover, after the implementation of the MDT, no deaths occurred in pregnant women with cesarean because of the regular follow-up, PAH-specific therapy, as well as meticulous postpartum care.

Our team have recognized that vaginal delivery is generally correlated with fewer postpartum hemorrhage and infections in general population, while the hemodynamic and physiological variations during labor may easily induce RV failure in pregnant women with PH. Cesarean section is favored by our obstetricians for the following possible reasons: (1) cesarean section avoids further increase in CO and hemodynamic swings associated with labor; (2) planned cesarean section allows the MDT to develop the relatively optimal delivery plan (e.g., stabilization of hemodynamics and evaluation of anesthesia); (3) the material mortality risk of cesarean delivery may be higher after failed trials of labor[10].

The optimal timing of elective delivery in women with PH has been controversial. Although there was no significant difference in the median delivery time in two groups, the post-MDT had a higher rate of preterm (55.6% vs. 34.7%, $p = 0.034$). Most preterm births were discussed and determined by the MDT. It is noteworthy that the mean baby weight of the post-MDT group was slightly heavier than that in the pre-MDT group (2469±652 vs. 2481±679 g, $p = 0.752$), probably because the number of IUGR of the former was significantly lower than that of the former. Furthermore, although the post-MDT group increased in iatrogenic preterm births, the fetuses of 75.7% (n = 25/33) were delivered in the near term (between 34 - 36 weeks of gestation)

Anesthesia Selection and Challenge

Epidural anesthesia perhaps is considered preferred anesthesia for PH pregnant women, while there has been rare robust evidence demonstrating that general anesthesia significantly increases maternal mortality[28, 29]. Before the MDT was established, three patients died under general anesthesia, and two died under epidural anesthesia (n=3/18, 16% vs. n=2/20,10%, $p = 0.595$), whereas no deaths were found in

planned cesarean section with general anesthesia. In the post-MDT group, general anesthesia tended to be the major with invasive arterial blood pressure monitoring by radial artery line in all patients if available. In addition, the central venous pressure (CVP) of 70 patients were monitored, with no infection complications founded. As revealed by the positive results, general anesthesia may be a safe anesthesia for pregnant women with PH with adequate preoperative preparation and intraoperative monitoring. General anesthesia is capable of more effectively controlling the changes of patients' condition during operation, except that it is likely to affect the fetus. However, the time from anesthesia to fetal delivery is usually very short, and our anesthesiologists adopts general anesthesia more.

Limitation

Our analysis has several potential limitations. We recognize that randomized assignment to MDT or no-MDT is the gold-standard to measure the effects of the MDT. However, conducting randomized clinical trials seems impossible for management of the MDT in pregnant women, so we used a quasi-experimental interrupted time-series to approximate a clinical trial. In addition, multidisciplinary consultation was frequently used to treat the severe women with PH before creation of the MDT. However, the above approach has inevitable drawbacks (e.g., timeliness and stability), so the MDT centered on PH pregnant women was established, aiming at streamline treatments and improving outcomes. Furthermore, this study was performed in a large tertiary pulmonary vascular disease center and may not apply to community hospitals, where PH experts is unavailable. Lastly, most data were collected from pregnant women with group 1 and group 2 PH at the single institution, so our results might not reveal the effect of the MDT on other types of PH. The above are important topics and should be explored in future research.

Conclusion

After the MDT was established, the therapeutic mode for pregnant women with PH has changed in our hospital, a tertiary referral hospital. Early termination of pregnancy and strict follow-up during pregnancy and postpartum played important roles in improving material survival. PAH-specific therapy as advanced therapy for pregnant women with PAH has been considered an essential part of control PAP during pregnancy. In general, urgent cesarean section is correlated with unstable hemodynamics, thus resulting in maternal death. Moreover, the multivariate logistic analysis found the severity of PH and NYHA FC before delivery as a risk factor for composite complications of pregnancy (maternal mortality, heart failure and urgent delivery). Accordingly, lowering PAP and improving cardiac function in PH patients with pregnancy and ensuring the safe delivery of the fetus are the focuses of the MDT. After the implementation of the MDT, no maternal death occurred, the percentage of urgent delivery and heart failure decreased significantly, and the percentage of PAH-specific therapy increased.

Abbreviations

ASD: Atrial septal defect; CHD: Congenital heart disease; CO: cardiac output; LHD: left heart disease; NYHA FC: New York Heart Association functional class; PAP: Pulmonary arterial pressure; PAH: Pulmonary arterial hypertension; PDA: Patent ductus arteriosus; PH: Pulmonary hypertension; RHC: right heart catheterization; VSD: Ventricular septal defect; WSPH: World Symposium on Pulmonary Hypertension;

Declarations

Ethics approval and consent to participate

The retrospective study (including free of informed consent) gained an approval from the review board of the Second Xiangya Hospital of Central South University. The informed consents of all participates are not able to obtain in this retrospective study. All methods were performed in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Chen WJ carried out the retrospective review of all cases, participated in the writing and organization of the manuscript. Luo J and Chen YS conceived of the whole study, and carried out the study design and correction of the manuscript. Chen JY and Li ZL participated in the design of the study. Qiu HH participated the analysis of cases. Li J participated in the study's design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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Tables

Table1.Baseline characteristics of pregnant women with pulmonary hypertension in pre-MDT and post-MDT groups

	Pre-MDT (n=49)		Post-MDT (n=54)		p value
	n. or median	%/range	n. or median	%/range	
Demographics and obstetric characteristics					
Age, years (median,range)	25	(20,44)	28	(18,40)	0.01
Nulliparous	37	75.5%	32	59.3%	NS
Weeks of delivery (median,range)	37	(31, 42)	36	(27, 40)	NS
Regular follow-up	26	53.0%	43	79.6%	<0.01
Classification and etiology of PH					NS
WHO group 1					
IPAH	1	2.0%	3	5.6%	
CTD-PAH	2	4.1%	1	1.9%	
CHD-PAH	30	61.2%	33	61.2%	
WHO group 2					
Valvular disease	14	28.6%	12	22.2%	
WHO group 5					
Single ventricle	2	4.1%	3	5.5%	
Double outlet of RV	0	0.0%	1	1.8%	
Aortic-pulmonary artery collateral circulation	0	0.0%	1	1.8%	
Severity of PH					
Mild	24	49.0%	20	37.0%	NS
Severe	25	51.0%	34	63.0%	
NYHA FC					
I	6	12.2%	5	9.3%	NS
II	25	51.0%	25	46.3%	NS
III	9	18.4%	20	37.0%	0.03
IV	9	18.4%	4	7.4%	NS

$p < 0.05$ represents a significant difference; Maternal age and weeks of delivery were analyzed by Wilcoxon rank sum text; Other data were analyzed through chi-square test and Fisher exact test; n number of pregnancies; % percentage; CHD congenital heart disease; CTD connective tissue disease; IPAH idiopathic pulmonary arterial hypertension MDT multidisciplinary team; NS no significance; NYHA FC New York Heart Associated function class; PH pulmonary hypertension; RV right heart; WHO World Health Organization.

Table 2 Treatment of pregnant women with pulmonary hypertension in pre- MDT and post-MDT groups

	Pre-MDT (n = 49)		Post-MDT (n = 54)		p value
	n	%	n	%	
Pulmonary-specific therapy	8	24.2%	22	59.5%	<0.01
monotherapy	7		12		
combination therapy	1		10		
oxygen therapy	34	69.4%	32	59.3%	NS
diuretic	20	40.8%	21	38.9%	NS
Digoxin or Cedilan	18	36.9%	16	29.6%	NS
Mode of delivery[a]					NS
Vaginal	2	4.2%	1	1.9%	
Cesarean section	46	95.8%	53	98.1%	
Anesthesia[a,b]					<0.01
General anesthesia	18	39.1%	38	71.7%	
Neuraxial[c]	28	60.9%	15	28.3%	
Monitored in ICU[d]	20	40.8%	43	79.6%	<0.01

$p < 0.05$ represents a significant difference; n number of pregnancies; % percentage; [a] 1 pregnant delivery and anesthesia information missing in the pre-MDT group; [b] Only including cesarean delivery cases: pre-MDT (n = 46), post-MDT (n = 53); [c] Neuraxial: epidural or spinal or spinal-epidural anesthesia; [d] pregnant women after delivery were admitted to ICU monitored at least 24 hours. MDT multidisciplinary team; ICU intensive care unit; NS no significance;

Table 3 maternal and fetal/neonatal complications in pre-MDT and post-MDT groups

Obstetrical complications[a]	pre-MDT (n=49)		post-MDT (n=54)		P value
	n	%	n	%	
Pre-eclampsia	4	8.2%	4	7.4%	NS
Premature rupture of membranes	4	8.2%	5	9.3%	NS
Postpartum haemorrhage[b]	2	4.1%	2	3.7%	NS
Heart failure	15	30.6%	7	12.9%	0.02
material death	5	10.2%	0	0.0%	0.02

Fetal/neonatal complications[c]	pre-MDT (n = 49)		post-MDT (n = 52)		
	n/mean	%/SD	n/mean	%/SD	
Birth weight (g), mean±SD[d]	2469	652	2481	679	NS
Prematurity	17	34.7%	30	55.6%	0.03
low birth weight[d+e]	21	43.7%	26	53.1%	NS
Neonatal death	7	8.2%	1	1.9%	0.02
IUGR[f]	16	32.6%	8	15.4%	0.042
naonatal anormaly	2	4.1%	3	5.8%	NS

$p < 0.05$ represents a significant difference; n number of pregnancies or neonatus; % percentage;
[a] 49 women in the pre-MDT group and 53 women in the post-MDT group; [b] pregnant women with cesarean section lose more than 1000ml of blood or with vaginal delivery than 500ml; [d] one and three baby weight lost in the pre-MDT group and the post-MDT group, respectively; [e] was defined as baby weight < 2500g; [f] IUGR defined as birthweight 10th percentile for gestational week at delivery; IUGR intrauterine growth restriction; MDT multidisciplinary team; NS no significance; SD standard deviation

Table4 Characterization of maternal mortality in pulmonary hypertension

Patients	Etiology	sPAP (mmHg)	Delivery timing (weeks)	Delivery mode	Anesthesia	Rescue therapy	Timing after delivery	Cause of Death
1	PDA	105	34	Urgent cesarean	Epidural-	dopamine+adrenaline +ventilator	3 days	severe preeclampsia, heart failure associated with multiple organ failure
2	PDA[a]	89	35	Urgent cesarean	General-	nitric oxide +epinephrine+dopamine isoproterenol+ norepinephrineventilator+CPR	10 days	persistent hypoxemia, circulatory collapse and hypoxic encephalopathy
3	VSD	57	33	Urgent cesarean	General-	epinephrine+dopamine +ventilator+CPR	within 24 hours	multiple organ failure, postpartum hemorrhage(1500ml)
4	ASD	87	38	Urgent cesarean	General-	dopamine+epinephrine +dopamine+ventilator	10 days	severe preeclampsia, circulatory collapse, hypoxic encephalopathy
5	VSD[b]	84	33	Planned cesarean	Epidural-	Nebulized iloprost+Nitric oxide+defibrillation	2 days	sudden ventricular fibrillation with RV systolic pressure as high as 132 mmHg

a left-to-right shunting developed into right-to-left shunting or bidirectional shunting(Eisenmenger syndrome; b postoperative pulmonary arterial hypertension ; ASD atrial septal defect; PDA patent ductus arteriosus; VSD ventricular septal defect; sPAP pulmonary artery systolic pressure; CPR cardiopulmonary resuscitation

Figures

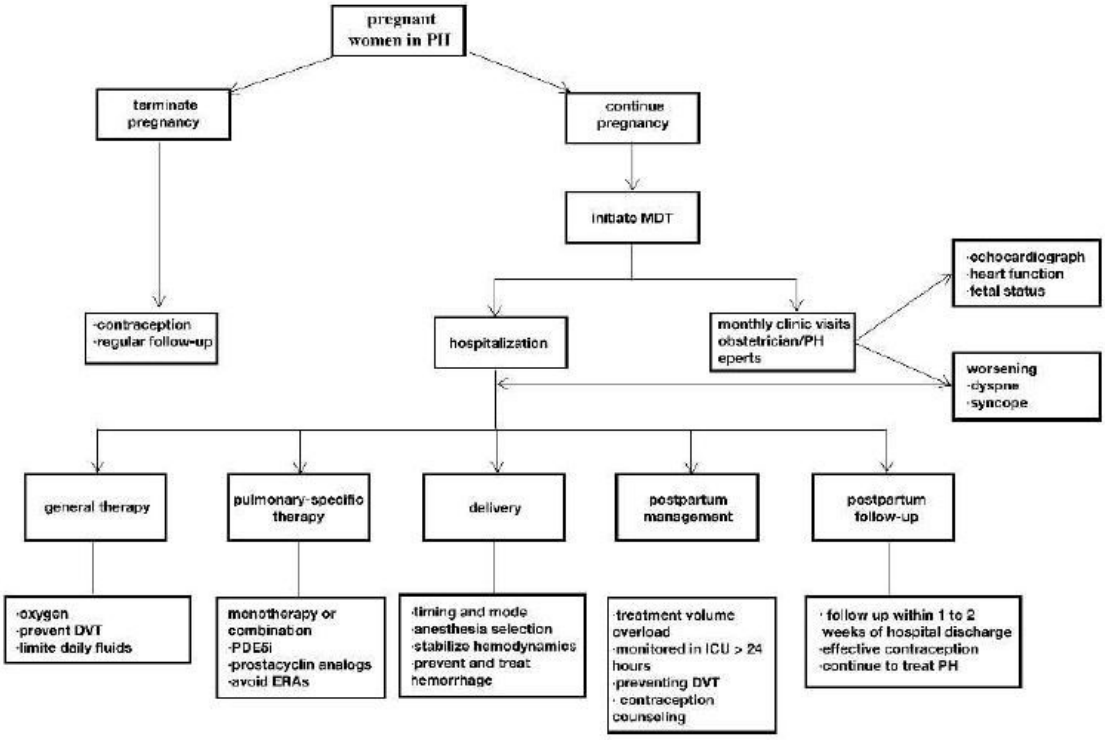

Figure 1

The treatment strategy of multidisciplinary team central on pregnant women with pulmonary hypertension

DVT: deep vein thrombosis; ERAs: endothelin receptor antagonists; ICU: Intensive care unit; MDT: multidisciplinary team; PDE5i: phosphodiesterase 5 inhibitors; PH:pulmonary hypertension

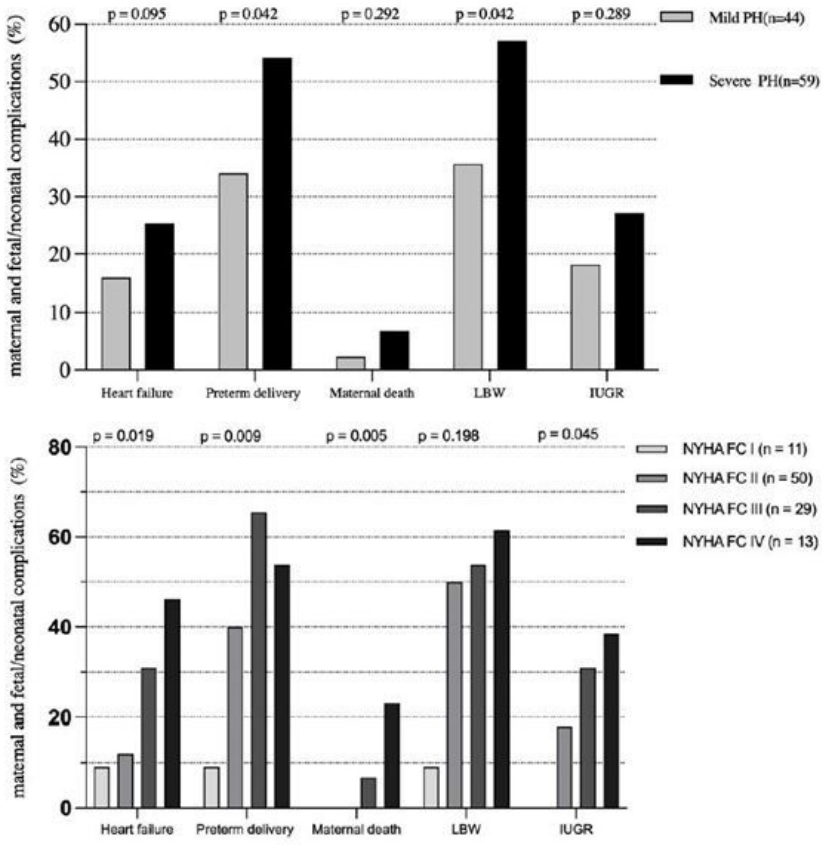

Figure 2

2(a) maternal and fetal/neonatal complications in different severity of PH

PH: pulmonary hypertension; LBW: lower baby weight; IUGR: intrauterine growth restriction

2(b) maternal and fetal/neonatal complications in different NYHA FC

NYHA FC: New York Heart Association functional classification; LBW: lower baby weight; IUGR: intrauterine growth restriction